Is Building Construction Approaching the Threshold of Becoming Unsustainable?

A System Theoretic Exploration towards a Post-Forrester Model for Taming Unsustainable Exponentialoids

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Is Building Construction Approaching the Threshold of Becoming Unsustainable?

A System Theoretic Exploration towards a Post-Forrester Model for Taming Unsustainable Exponentialoids

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Human beings become builders by building."
Aristotle, *"Nicomachean Ethics," 2.1.1103a35*

Technology is a neutral means or human activity – a kind of truth revealing – that sets up and challenges nature to yield (release and transform) a kind of energy that can, at will, be independently stored, and transmitted (*distributed*)."
"The essence of modern technology starts human beings upon the way of *THAT* revealing through which reality everywhere, more or less distinctly, becomes resource."
Adapted from M. Heidegger, 1954, "*The Question Concerning Technology and Other Essays,"*

"The bet or wager of the century is not some unqualified conquest of nature but the replacement of the natural milieu with the technical milieu. The modern gamble is whether this new milieu in contrast with the natural milieu will be better or even possible."
J. Ellul, 1954 *"Technology or the bet of the Century*"

"Perhaps the development of technology, like the development of science, should be viewed as proceeding within the framework of paradigms."
T. Kuhn, 1976, *"The Structure of Scientific Revolutions."*

"The solution to the problems of technology is not less but more and more comprehensive technology."
Common phrase, C. Mitcham, 1994, *"Thinking through technology: The path between Engineering and Philosophy."*

"Situations in life often permit no delay; and when we cannot determine the method which is certainly best, we must follow the one which is probably the best…if the method selected is not indeed a good one, at last the reasons for selecting it are excellent."
Descartes 1989, quoted by Koen, 2003, "*Discussion of THE method,"* all-is-heuristics.

PREFACE

Adapting the words of Koen (2003), sustainability is an issue touching the larger issue of survival. “Considering the 100 Million species that are estimated to have become extinct since life first appeared on this planet, Homo-sapiens is a three hundred thousand year experiment.” Overpopulation, resource consumption and pollution are a short term challenge and a long term major problem with possible catastrophic consequences. As a general rule, no argument is improved by exaggeration because the reader/listener immediately becomes suspicious of what is to come. Therefore the study is limited at the front-end of the scope to short term challenges, keeping in mind the possible consequences of our life-styles in thousands of years to come.

In general a dissertation is focused and narrow according to selected criteria and assumptions. The intent of this dissertation is not to exclude other areas, sectors, industries that are related and can benefit from the insights of the dissertation. Civil, heavy industrial and other types of construction are sectors that contribute to the problem and therefore must be part of any solution. Future studies may consider the subject of analyzing and comparing the similarities and differences of the contributions of the different sectors using this dissertation’s findings and methodology as spring board.

Familiarity by the author of the building industry, limited time and resources, availability of extensive published research information and data that has a fit with the nature of the problems as framed by the dissertation are assumptions and limiting criteria on the scope of the work selected.

ACKNOWLEDGEMENTS

I am fortunate and grateful to have been selected by Dr. Roozbeh Kangari to start the Building Construction Summer Study Abroad Program in Paris by teaching Construction Issues and Initiatives and a Lab for Sustainable Design which provided the opportunity to research, test and present the findings to the attending students. A special word of thanks to the thirty-eight Building Construction students in the Study Abroad Programs (2004, 2005, and 2006) in Paris: By allowing me to test the dissertation heuristics I was able to see the puzzle more clearly. Some of their assignments were used to verify and confirm my own findings; A few graphs were an improvement on mine, and if used, credit is noted in this dissertation. I am encouraged by their ability to grasp the importance of the issues and hope that by the confluence of the Paris milieu, rose-garden experience, subject matter and further curiosity, some may end up doing graduate studies research in the industry or academia. It will be a pleasure to collaborate with them in their Ph. D. program!

Professor Augenbroe provided the social, academic and scientific milieu, especially in times of trouble as well as the tradition-bound technical standards-of-success and failure so essential when undertaking an innovative puzzle solving research. He has been a link to the scientific community, a gatekeeper of world leadership renown, and an enabler to seek a new paradigm allowing the exploration of the fringes of the profession. Professor Augenbroe has become the one person with whom, a la Kuhn, "*I have been able to communicate in incomplete sentences*."

I am in debt to all those sources that have prepared the groundwork upon which I am standing deserves the most sincere thanks for bringing the debate and insights on the issues to perspective in their publications. Dr. Lauri Koskela deserves especial mention. When we met in

Salford, Dr. Koskela stated that he had prior reservations for someone taking on this untypical broad topic of interest, knowing that pre-paradigms require philosophical and experiential insights. After we met at the University of Salford's Post Graduate conference not only he agreed to be an external reader but encouraged the dissertation. Dr. Koskela's publication on "*The Metaphysics of Production*" with Dr. Kagioglou brought a definite smile as we are beginning to take seriously Philosophy (Hegel 1975) in our search for theoretical foundations and clarity of thought. Dean Thom Galloway and Brian Bowen have been extremely valuable and provided a needed source of constructive criticism, guidance and encouragement. Both are a true joy in the role of external readers who in the process have accepted me as a friend and colleague; An honor that I cherish dearly. Dr. Linda Thomas, my mentor, has encouraged and sustained me though this unconventional quest, and I am in great debt for bringing to my attention Koen's book on *"Discussion of THE Method"* where all-is-heuristics. When all is said and done, this dissertation claims to be a small addition to the world's heuristic regarding the state of the art in approaching complex problems. My good friend Jeffrey Beard provided a sounding board in early conceptual thinking, and suggested reading Landes, Max-Neff and Maslow among others.

Lastly, this work is dedicated to my wife Earline, my most devoted fan, providing life-giving encouragement during times of crisis, ample time during long hours of research and writing, and listening to the internal and external debate of issues, not expecting that merely because my arguments are logical, they will be compelling. Earline was able to 'see' early on that the shortest distance between two points is not a straight line, and had unwavering faith in my knapsack of professional experiences.

José L. Fernández-Solís,
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July 30, 2005

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SUMMARY

The construction industry is a major contributor to emissions and pollution and is a main world resource consumer (prime matter, energy, labor, capital). Because of this, the industry is formulating short and long-term sustainability targets. Europe has issued long-term objectives that will require huge adaptations of the industry. The US is slow to adopt a similar agenda, but will soon realize that voluntary incentive programs such as LEED, all of the presently conceived conservation, green and high-performance sustainable measures and Carbon Trading strategies, that even if adopted globally, are vastly insufficient to achieve the 'necessary targets' in a timely manner. The problem starts with the need for understanding what is meant by 'necessary targets.'

xiv The dissertation starts with a verification of the global challenges that face the industry. Given its projected growth in resource consumption and emissions generation in response to global population growth and improving standards of living, it will be shown that these trends point towards an unsustainable future for both resource consumption and emissions generation. The trends are analyzed in the form of so-called "exponentialoids[1]" as introduced by García Bacca (1989). It is shown that the industry will become unsustainable within the next 75 years unless substantial reductions in emissions and resource depletions can be effectuated, or, in other words, the exponentialoids can be tamed. The 'necessary targets' are understood in this dissertation as unsustainable exponentialoid growth.

There are no reliable studies that predict whether the required reductions in ecological impacts can actually be realized, and if so, on what time scale. In fact, currently no available

[1] The term exponentialoid is used to denote a force with multiple and complex sources. Exponentialoid is a key term encompassing major concepts that is further elaborated and expanded in collateral material presented in the appendices such as Appendix I The nature of Exponentialoids.

system representations of the industry can serve as the basis for studying long-term sustainability through the twenty-first Century. It is articulated that we live in a post Forrester era in which hard dynamic systems are no longer accepted as adequate representations to study the dynamics of complex systems such as economies and industry sectors. Uncertainties, capacity for self-organization, adaptability, inventions, economic conditions, entrepreneurship, the role of regulations, etc. call for system thinking which is not based on reductionism but analyzes complexity (Lewin 1993) to its full extent, in order to construct a novel "worldview[2]" of the industry. The dissertation argues that such a worldview requires a philosophical induction (a theory) of the nature of all the forces that move the industry and a mechanism for understanding how complex forces aggregate and affect an exponentialoid.

The answers provide an articulation of the complexity of the construction industry. They expose the shortfalls of current research models inspired on Forrester's (1971) work and his followers as a way to prepare the grounds for a heuristic/theoretical new approach to complex problems.

The construction industry or sectors 'must' contribute to the taming of the exponentialoid. However, the 'industry" is complex, amorphous and autonomous[3]. There is no champion or mechanism to direct a concerted 'must' response of industries or sectors, except perhaps in case of multiple catastrophic events of similar nature where a focused (most likely

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[2] Worldview definition adopted from the McGraw-Hill Online Learning Center of the Central Connecticut State University, found in http://highered.mcgraw-hill.com/sites/0072549238/student_view0/glossary.html : The collective interpretation of and response to the natural and cultural environments in which a group of people lives. Their assumptions about those environments and the values derived from those assumptions. Other terms that encompasses the concepts of worldview to some degree or another are: paradigm and mindset. According to Popper a worldview is a subjective state, consciously, subconsciously or unconsciously present which filters or frames the way reality is perceived. Popper's method of analysis will be expanded later on.

[3] The popular concept of construction as an 'industry' and the epistemological ramifications are further elaborated in Appendix L.

governmental) intervention may facilitates the marshalling of the necessary public and private forces; an option alluded to in the dissertation, but not currently in the horizon.

Current national and international response to the problems, the dissertation articulates, does not appear to have the capacity (in direction and magnitude) to tame the consumption and emissions exponentialoid. There are multiple stipulations behind this observation: We have not looked at the nature of the problem, from the perspective of the 'open to infinity' (a characteristic of exponentials) and we have not identified how multiple elements influence exponential growth as presented in the dissertation. Furthermore, the models, such as Forrester's that have been used in the past, based on algorithms, are not adequate to capture the nature of the complexity of the elements that influence change. This inadequacy stem from a worldview biased towards the quantitative (magnitude) element of reality. These models do not take into account the other elements (origin and direction - sense) because it does not account for the vectorial nature of forces in its worldview.

This brings us to the pre-paradigmatic (broad) approach of the dissertation to provide a frame for targeting in the next phase of research: identification of how specific vectors influence the exponentialoid (testing of the hypothesis) and identification of the measurements that are needed from the 'industries' or 'sectors' to determine what level and quality of effort is needed. That is how can the industry align the sense and direction of its efforts with the problem, as well as determine new sources (origins) of technologies that have the potential to scale up (reach required magnitudes) and relieve the current exponentialoid system of supply and demand (modeling the hypothesis with current and theoretical scenarios).

Assumption (2) is also on target in that any correction within the meta-system of construction takes place simultaneously, while the industry continues to create a problem and adapts to solve a problem. The historical model(s) of the Industrial Revolution(s) testify to the capacity of the industry of industries to adapt to internal and external forces. Examples are the tinkering, thermodynamic, molecular and atomic revolutions and the effect that they have exerted to the different industries that compose the construction industry.

Some researchers as well as critics have noted that changes in the industry have been relatively slow in relation to other industries such as electronics. The dissertation quotes scientists, economists who believe that the step from the atomic to the nano technologies has the capacity of becoming the power that propels the next industrial revolution. Accordingly, the capacity of this next industrial revolution may dwarf all preceding revolutions in a cumulative growth pattern with exponentialoid characteristics.

The dissertation examines the current understanding of the Theories of Complexity (TOC) in general, and building construction complexity specifically, in preparation for a deeper understanding on how sustainability and exponentialoids relate. Sustainability, in our understanding, is beyond that of waste containment, the use of renewable resources, greening the industry, creating high-performance buildings, providing for the cost of the environment, carbon trading, renewable energy sources etc… This is an understanding of sustainability of an object that has to be made to last, use less resources, be efficient, compensate for damages, and account for life cycle costs.

In this dissertation we will be talking about an industry (viewed as the generative process of objects). This requires an extended meaning of sustainability. An industry is thought of as sustainable if its processes can be managed to meet certain demands. Those demands are identified in this dissertation and quantitatively identified as the major forces confronting the industry (exponential growth, exponentialoids). If the industry properly manages the processes, the elements that influence change, it may bring the overall process from being unsustainable to sustainable. In our case then, sustainability has become a property of process rather than of object.

The general method consists of identifying the 'elements that influence' an exponentialoid growth. This is achieved first through the use Historical Thinking and applying to it Causal Loop Analysis (CLA) as an interpretative tool. The 'elements of influence' found in Malthusian Positive Checks was the initial spark that highlighted the complexity of 'elements that influence' and how they affected the population exponentialoid and uncovered in a seminal form a method for understanding the dynamics of an exponentialoid. From this study of the Malthusian Positive Checks a pilot heuristic/theory[4] was derived, and a novel method was proposed as the subject of this dissertation to study how the 'elements of influence' interact with an exponentialoid with a focus on the construction industry as the System of Interest (SoI). This approach is contrasted with Pearce (2006), Turner (2006), Briscoe (2004) and Kohler (2006 - Economic-Environmental), Forrester (1971), and Sterman (2002 - Systems Dynamics), Chichilnisky (1997 - Economic/Environmental-Mathematical), and followers' Carassus (1998, 2004 – Mesoeconomic/sector system) to highlight different approaches to complex problems, worldviews and paradigms.

At this juncture, the question of what is sustainability has been re-framed using a different worldview. **Sustainability is re-framed, in a new heuristic concept, as the (artificial) force that tames an unsustainable exponentialoid.**

[4] Theory is used as a model of the universe or a restricted part of it. A theory exists only in our minds and does not have any other reality (according to Hawking 1998, whatever that might mean). A theory is a good theory if it satisfies two requirements: It must accurately describe a large class of observations on the basis of a model that contains only a few arbitrary elements, and it must make definite predictions about the results of future observations.

The next task is to apply this concept to building construction. Historical Thinking and CLA of the several Industrial Revolutions, are used as vicarious repositories of the 'elements that influence' exponentialoid change in construction at a time of rapid population growth.

The change dynamics of the industry (Egan 2002; Ogunnaike and Ray 1995) are more clearly and directly perceived in the study of a specific building type. Of the many historically available building types, two were selected, the hotel and the high-rise building. Research indicates that the hotel is an example of a building type that is typically a good repository of the latest invention and innovations as they have appeared in history. However, research also indicates that the high-rise (Eisele and Kloft 2003) building is a more complex technical building type (although hospitals are even more complex, Strauss and Schatzman 1963) that required the advent and evolution of multiple technologies. The high-rise building was ultimately selected for the study[5] of the change dynamics of the industry due to the global fascination with the building type, available historical data, subject familiarity, and time constraints on the research. The air conditioning and elevator systems were identified among other sub-systems as surrogates of the changing dynamics in building construction and are analyzed using Historical Thinking and CLA to identify the 'elements of influence' and test our definition of sustainability.

Sustainability, as the force that tames exponentialoid growth, is presented by defining our understanding of the vectorials in the elements of influence that have identifiable: origin, direction (sense) and magnitude. An example of how the heuristic/theory works is presented pending future studies that are needed to supply the necessary data required for a working model. As indicated, this is the beginning of a novel worldview, and method of analysis that rather than

[5] The US Construction Industry generally breaks down into three distinct building categories: Residential (approximately 50%), Non-residential (approx. 30%), Civil/infrastructure (approx. 20%) with figures varying from year to year. High-rise and hotels probably do not exceed 10% of non-residential or 3% of the total.

conclusive, identifies a large bodies of increasingly detailed research work to be performed in the future.

Lastly, a system theoretic basis is presented to showcase how instruments for regulatory bodies and governments may be set for sustainability agendas under the proposed approach for interpretation that are both realistic and linked to adequate and effective measures.

PS. After the dissertation defense that took place October 6, 2006; three publications have surfaced that have significant bearing on the dissertation premises: The Stern Review Report, James Kynge (2006) book China Shakes the World and Architect (2006) premier issue in November.

Sir Nicholas Stern (2006) published the Stern Review Report commissioned by the British department of the treasury, the most comprehensive scientific report on the state of the art knowledge regarding emissions generations and climate change. Although the report is geared towards the economic impact of climate change due to emissions generation, it affirms the criticality surrounding this issue. Part I, chapters one through four are a must read for those interested in the subjects underlying this dissertation. (See Appendix M)

Kynge (2006) is the equivalent of HUMIT, human intelligence asset in place, in Beijing during the last 20 years, documenting the forces that are propelling this unprecedented growth in both resource consumption and emissions generation. Therefore his book is also a must read and a brief digest is presented in Appendix M.

The premier issue of Architect (2006) states: In 2000 the estimated total square feet of space in the USA is divided 50% between residential and non-residential. The amount is set to double in 2030 due to a predicted population increase of 83 million. The numbers are heuristic but the principle is the same: large amount of population, even in a developed country, are poised towards an unprecedented demand on construction resources and emissions generation.

CHAPTER 1

INTRODUCTION

We travel together, passengers in a little spaceship,… preserved from annihilation only by the care, the work, and, I will say, the love we give our fragile craft.
Adlai Stevenson, in his last speech, 1965 (Speth, 2005).

In this chapter, we are going to address the motivation for this study because research shows that currently there is not a deep understanding of the nature of the challenges confronting the industry. We will focus on the problem and the relevance of the problem as it affects policy makers, building construction executives and critical planners that include public officials as well as academicians. We are going to focus on the search for a methodology that can be used to address an understanding of the problem, the challenges and the possible solutions to establish a base for this dissertation. What we have found in the research of methodologies, as well as in the analysis of the problem, is that currently we do not have a clear framework that frames complex problems (Williams 1999). The primary suspect for this lack of a tool for analysis is attributed to a deficient worldview, a lack of philosophical definition of the major themes and the absence of conceptual schemes, albeit heuristic/theoretical, that apply to construction. The implications of these findings form the foundation for the argumental steps in the following chapters.

There is considerable and varied research and thinking taking place in the industry. There is also an ongoing debate on whether the construction industry should become more like other manufacturing industries (Heim and Compton 1992; Hopp and Spearman 1996; Howe 2000; Hounshell 1984) in an effort to internally gain efficiency (Emerson 1917), diminish fragmentation[6] (Carassus 1998, 1999, 2004) and externally become more ecologically friendly and sustainable. These lines of thought indicate that the industry has reached a crossroad with the traditional (Syben 1993) ways of constructing and thinking about construction. This is supported by CIB 1997, CIB 2005, Pearce and Turner 1990, Pearce 2006 (also see Foran et. al. 2004), and Kohler 2006.

The challenging topics considered in the second chapter, to frame the direction we are taking, are varied such as: the expansion of population, the universal aspiration of increasing affluence, the depletion of natural[7] resources (Moreaux and Ricci 2005) and the increasing environmental degradation. The result is an extraordinarily difficult to reverse global environmental degradation, adverse climate change, and technological demands on productivity and processes.[8] Have we crossed a threshold with nature? If so, what are the primary and secondary implications for the construction industry? Can the industry, a significant contributor to the current predicament, respond in such a way as to ameliorate the aggravating circumstances?

In Chapter 2, we will see that the nature of the problem is exponentialoid growth at all levels. The responses, needed to reverse exponentialoid growth in multiple complex and interacting systems or meta-systems (term that will be explained in detail later) are of incredible magnitude. The complexity and synergy of these challenges reveal more than the incidental,

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[6] A characteristic of the construction sector is its fragmentation into a large number of segments, themselves composed of numerous small and medium-sized companies.

[7] Natural is defined by Garcia Bacca (1987) as that whose finality reaches its end. That is because of finality the process of growth, development and evolution is stopped, because that is its end, nature is perfect. In contrast the artificial is always open to descend into obsolescence through novelty, innovation thus its finality never reaches its end.

[8] According to Tom F. Peters (1986) "*Architecture, being a pre-Industrial Revolution field, is essentially product oriented. Therefore aesthetic thought in architecture is mainly concerned with the finished object. Engineering, on the other hand, being a field formed by the nineteenth Century is intrinsically process oriented. Engineers are just*

giving reasonable doubt that the industry can respond to the challenges at this time and in the near future based on current R & D, trends and initiatives, what is called the frontier of building construction[9] science. Because we are dealing with complex systems both in nature and in building construction, we can not escape the need to devote Chapter 3 to an understanding of the systemic nature of the building construction industry and constructively criticize the approaches, such as Forrester (1971) and Pearce (2003) highlight the problem and current solutions (also see Beise and Rennings 2005; nCRISP 2004). Again, we are presenting this information at this time only to indicate where we are going with our methodology (chapter 1) and the problem framing (chapter 2).

In this dissertation we would like to maintain two Socratic attitudes: The first is based on the paradox that not knowing allows the possibility of openness to the truth; The second is the tradition of raising 'the question' rather than providing 'the answer' in the tradition of Heidegger (1962) who verbalized that more than anything else, questions, difficulties, or problems are what philosophy is about. Heidegger was inordinately suspicious of all answers or solutions, the underlying attitude of this dissertation. We are also aware that this dissertation leans toward a heuristic/theoretical approach since "Situations in life often permit no delay; and when we cannot determine the method which is certainly best, we must follow the one which is probably the best…if the method selected is not indeed a good one, at last the reasons for selecting it are excellent" (Descartes 1989, quoted by Koen, 2003, "*Discussion of THE method,*" all-is-heuristics).

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as concerned with process of calculation, manufacture, erection wear and maintenance as they are with the finished product." This is another use of Foucault's (1994) differentiation between "Classical" and "Modern."

[9] Fitchen (1986) defines building construction as the aggregate comprising all those undertakings and practices involved in the actual production of the artificial world of structures that provide shelter and viable environment for people, their goods, institutions and life style.

1.1 MOTIVATIONS FOR THE STUDY

Motivation for the study is concerned with answering the following questions: Why this study? What is important with this study? What can we do with this study? What does it all mean? So what? This study will approach the answers from the perspectives of three stakeholders: Policy Makers, International Building Construction Executives, and Critical Planners (philosophers, think tankers, global strategists, and academicians).

One part of this study concerns all three stakeholders: The magnitude of the synergy of the challenge to the building industry when, at a macro 'industry' level, the issue of population[10] is added to the mix of sustainability and environmental issues. The initial focus of this dissertation is to answer the following query: Are we asking the correct question regarding the forces behind the challenges that are related to the building construction industry's capacity for change? Posed in the singular: What is the problem? Who says that there is a real problem? What do we know about the problem? What changes are needed, and in what magnitude are they required to address the problem?

A major motivator is to highlight each challenge individually, collectively and at its full complexity (as understood in the state of the art research) so that the stakeholders can clarify their own vision and mission statements. Although the challenges are better appreciated from a

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[10] Malthus published his *"Essay on the Principle of Population,"* (Malthus, 1983) in which he predicted that natural global population growth would surpass the global food supply and recommended measures to reduce the birth rate. His theory was dismissed during the following centuries because of the prevailing belief in the power of science and technology to overcome population growth demands. His theories have been resurrected because of their application to a growing consensus on growth limits, the need for sustainable development and increased waste and pollution's detrimental effects on the environment.

macro perspective (such as industry, general economy level), the final study will also frame the challenges at a micro scale (such as project and firm) when appropriate[11].

To achieve this end, the hypothesis is dedicated (emphasis added for the area in question):

> A better understanding of the systemic nature of the building construction industry is needed to reason about its capacity to change in the face of critical challenges.

According to Heidegger (1962), when a system breaks down, the background of that system becomes highlighted, similar to what happens when a catastrophe strikes. Examples of this are the 9/11 event and hurricane Katrina striking the New Orleans region on August 29, 2005[12]. The critical challenges, although not wholly appreciated by the industry at the present time, are beginning to highlight the holes in our industry that has no peculiar theories, in our practices venerable and ancient but fraught with discontinuities and plagued by lawsuits and adversity, and our organizations characterized by fragmentation (Pyke 2002). Such is the background of our "source of resources" that is the building industry which can celebrate marvelous successes (i.e. Bowley 1969) but has also contributed significantly to the current state of affairs.

This dissertation purports to clarify the central issues surrounding the forces behind the challenges, imbued with an 'intensity of feeling about a moral commitment to human

[11] According to CIB Agenda 21, document SB2000: "Strategies for reaching a sustainable built environment must reflect varied regional conditions and priorities, and different models for implementation: think global, act local." We take this insight to the issues of population/demographics and environment/climate change as well as to their synergies.

[12] Katrina was a category 3 with sustained winds of 125 mph, a surge of 34 ft. The number of houses in New Orleans with more than 4 ft of water is greater than 108,000. As of April 2006, the cost incurred is approximately $12-15 Billion US dollars; property damage is estimated at $75 B, the costliest in US history up to now; estimated cost to repair New Orleans is $200-300 B. (Brookings Institute, www.hurricane-katrina.org; msmbc.com accessed 5/20/06

betterment.' The study of the forces behind the challenges is of interest to the Policy Makers, Executives and Planners in itself but above all, because of their impact on the building construction industry's systemic nature, the current paradigm, the mechanisms for change, and the capacity for change as follows:

1.1.1 Policy Makers

Policy makers and governments are aware of the issues, attested by international negotiations with a now set protocol. This protocol includes several stages. The first stage is of problem identification, fact finding, and agenda setting. The focusing events revolve around establishing that the problem is real and not just scientific speculation followed by commissioning further research and fact-finding. The second stage is convention and protocol process that includes bargaining, and agreement on what actions to take. Lately there is a mounting eagerness to start negotiations in the face of uncertainty, which contrast with an earlier reluctance to act until all the facts were uncovered.

The impressive goals of the international community are not followed, according to Speth (2005), by clear requirements, targets and timetables characterized with a bargaining to avoid cost commitments and structural changes in the paradigms of society. The situation is different in the 'geological stable and up to now insulated' building industry. Policy makers in the building industry are awakening to the seriousness and possible consequences of the issues of sustainability and the environment requiring major changes in the acquisition and delivery of services and products (Nightingale, 2000).

For example, the *"Challenge of Change in Construction"* was the theme of the CIB's *Revaluing Construction 2005* international conference in the Netherlands that called for a "radical change". The conference invitation and its proceedings portray "radical change" as how to respond to the pressures of globalization, how to change the image of traditional bound building construction (Syben 1993), how to achieve a modern and efficient industry, how to share lessons learned (Fox et al. 2002) from those that have accomplished or tried some form of change, what promotes change and locating the pitfalls, the best tools for change (including new procurement methods), and how the construction industry (National and International – Strassman and Wells 1988) can learn from the experience of change in other industries.

In Heidegger's (1962) line of thinking, construction is so certain about how to design and construct with a method or procedure that it does not recognize its own limits and therefore 'does not know itself.' In the words of Ortega y Gasset, 1939: "People know how to realize any project they may choose even before they choose some particular project."

Research themes confirm that the "challenge of radical change in construction" currently centers on how construction can become more like manufacturing (Fisher 1993), that is using the techniques of industrialization (Mumford 1934, 1967, 1970), prefabrication[13], modularity and mechanization[14]. Is the reason that construction wants to become manufacturing because it does not have its own body of theories? Or is it because 'construction' is in a paradigm shift mode, from one that has lasted several thousands of years? Or if Construction has its own paradigm is it that 'not being like manufacturing' has created an identity crisis? This study proposes that 'how to become like manufacturing' is not the right question to pose, but if change is perceived as essential to the industry, the question should be: How can we better understand the systemic nature of the building construction industry? This dissertation is motivated in discovering a

[13] Prefabrication is one form of industrialization based on the industrial manufacture of building components off-site or near-site.

framework for analyzing the change mechanisms embedded in the systemic nature of the industry with respect to its capacity for change in view of identified pressing challenges.

The first gut feeling from this study is that the CIB 2005 conference alluded 'radical' changes may need to be much more radical in nature if we are to meet the challenges, as understood and presented in this study. Therefore policy makers will benefit from the answers to the following questions posed in this dissertation: Can we come up with a theory, or a fundamental framework for better understanding the nature and magnitude of the challenges? As noted above, this and other questions led to the following hypothesis with the emphasis added to the issue at hand:

> A better understanding of the systemic nature of the building construction industry is needed to reason about its capacity to change in the face of critical challenges.

Our hypothesis is that unless we gain a better understanding of these mechanisms we will not be able to predict the industries' capacity for change. As a result, policy makers will not be able to predict how the industry can respond to the different challenges and their synergy, nor will regulators be able to assess both the viability of new requirements posed upon the industry[15], and the time frame in which they could be met. These constraints and challenges are forces that put the industry to the test in adapting to major changes; however is it realistic to expect the industry to change in such a time frame? How and how fast has the industry changed in the past

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[14] This move in the industry was accelerated after WWII when production techniques learned from the industrialization efforts were applied to the private sector.

[15] For example, Kyoto Protocol urging developed countries to reduce CO_2 by 5.2% by 2010 and Agenda 21 (U.N. Conference on Environment and Development, 1992, Rio de Janeiro, Brazil) recommended 2,500 actions to deal with our most urgent environmental, health and social problems. See also World Summit on Sustainable Development (2002) Johannesburg, South Africa (identifying population growth, poverty, depletion of fresh water, food security, use of sustainable energy sources and land degradation-habitat loss as the major world problems.

and how fast can the industry change in the present time based on current trends, initiatives and research and development (R&D)? What national and international treaties should be enforced?

Population growth, depletion of resources and impending possible catastrophes[16] driven by adverse climate change (Arnell et. al. 2004; Frankhauser and Tol 2005) comprise a set of time driven challenges, pointing that 'time is of the essence' and 'sheer number' is driving the challenges. FT10/20/06 reports that Britain and the Netherlands warned the EU of looming climate catastrophe by stating that "the world is only 10-15 years away from "a catastrophic tipping point."

If the challenge requirements posed upon the industry are real in scope and magnitude, and the time frames are constant, the variable becomes the magnitude of investment on R & D needed and where the effort of the R&D should be focused to bring about the necessary timely changes required to meet the challenges. We need a better understanding of the systemic nature of the building construction industry regarding the embedded mechanisms for change before we attempt to answer those questions.

1.1.2 Building Construction Executives

Building construction executives, in a market driven economy, have primarily paid attention to the bottom line. Natural resources: minerals[17] such as steel, copper, bauxite, selenium, alumina, zinc, ferro-molybdenum (stainless steel) and fossil fuels have doubled in price within the last two years (2004-5). These substantial price increases are unlike those seen in the 1972 temporary spike in one sector, energy (US EIA 2003) – fossil fuels, the price increase appears to be

[16] Catastrophes are used in this study as the cause of destroyed buildings by forces such as those of earthquakes, wind (hurricane, typhoon, cyclones, tornados), fire, landslides, volcanic eruptions, tsunamis, floods and those that may be caused by events that have a force beyond the 100 year design thresholds, such as structural or curtain wall failures, mechanical and electrical failures, etc.) that requires replacement of existing buildings.
[17] Minerals: high-grade metallic ores

permanent and the prices are across a number of different resources (Moreaux and Ricci 2005) pointing as the most likely source of this price increase to a recent multi-national exponential growth of construction activity (Brown, 2005b). The primary executive concern has been on the economy, resources and the transformation of those resources in ways that increase capital, produce value, and lately are done with a growing sensitivity to sustainability and environmental[18] issues (that is, if they can be worked-in with the primary strategies of profitability and long term plans). This qualification indicates the subjective nature of current sensitivities to environmental drivers at this point in time.

The question of interest to the executive is: are we living out the interest on the natural endowment or have we begun to consume the endowment itself (Brown, 1981)? Living of the endowment means scarcity of resources, the resulting prices that affect the 'bottom line' that does not take into consideration the possible economic effects of inflation, recession, the cost of environmental degradation, social and cultural costs, etc.

Regarding the inputs for example: Cement, lime, glass, paper, non-ferrous metals and steel industries are major energy intensive construction resources. Regarding the outputs: Buildings, as a finished product as well as the construction process, are estimated to consume approximately 33% of the total global energy production (US EIA, 2003) Construction, both new and renovation, a major global economic force continues at a frantic pace. The Pearce Report (2003) and subsequent development (Pearce 2006; nCRISP 2004) begin to tie economic-accounting construction metrics to sustainability in an ambient where international conventions

[18] Ernest Kapp (1845) who coined the phrase 'philosophy of technology' sought to relate history to Karl Ritter's new science of geography. Kapp's 'comparative universal geography' anticipated what today might be called and 'environmental philosophy.' For Kapp, the external colonization of the natural environment is complemented by an inner colonization of the human environment. History is the differential record of human attempts to meet the challenges of various environments to overcome dependence on raw Nature.

are not set thus impeding valuable comparison. Globally and nationally, the sustainable and ecological initiatives pale in comparison to the sheer number of new construction alone. Awareness does not yet exist at the global, national and firm scale of the nature, magnitude and implications of the changes to the industry and what is needed to meet the challenges.

Most of the focus of current trends and initiatives in the field are on 'process.' In other words, a building's process potential, under perfect circumstances during design and construction, may achieve significant savings in cost and time while maintaining quality when benchmarked against similar building types and of equivalent quality. If this level of efficiency[19] could be achieved consistently and throughout the industry, would it be sufficient or a major contributor to meet the challenges? There are a few thousands project done under LEED (Watson 2001); Even if all the projects in the world were done using LEED, would this be sufficient or a major contributor to meet the challenges? If we apply all known renewable energy source, green and high-performance technologies to building construction what is the magnitude of the results in concrete terms? These trends, initiatives and research and development efforts are where the industry is placing its hopes for the future but as we have stated, they may not be addressing the right question to begin with: what is the nature of the forces confronting our efforts towards sustainability?

Executives can benefit from the answer of this dissertation query: Is there something that we need to understand better about the industry so we can better manage the challenges that are coming (and therefore be profitable, increase market share, exploit opportunities, find the right thing to do and then do it right, at the right time, gain differentiation, etc)? How can we position

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[19] Efficiency (Mitcham 1994): "engineering is the art of applying science to the optimum conversion of natural resources to the benefit of man," "the conception and design of a structure, device, or system to meet specified

our companies strategically for a mutual benefit of the artificial (Simon 1969) world and the natural world? These and other questions led to the study hypothesis, with emphasis added:

> A better understanding of the systemic nature of the building construction industry is needed to reason about its capacity to change in the face of critical challenges.

The demographics indicate where the growth is, the aging population issue, even population decline, but that is known. What is not known are the forces of the change that scarcity of resources and the effects of emissions through adverse climate change[20] can create on both the economy (Arnell et. al. 2004) and the way the industry operates and a clearer understanding of the drivers behind those forces!

The industry wide issue regarding the input and output of materials is the question of whether the building construction industry has the capacity for radical change while in the continual process of creating capital projects. Industry claims that 'technology'[21] is the wand that will bring the needed solutions (echoing Mitcham's, 1994 common phrase: "*The solution to the problems of technology is not less but more and more comprehensive technology*") a statement that will be analyzed within the scope of this study.

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conditions in an optimum manner is engineering," "the essence of engineering is design, planning in the mind a device or process or system that will effectively solve a problem or meet a need."

[20] As we shall see climate change between 1000 and 1700 with the ending of the little ice age was a 'generator of change' beneficial to agriculture and an element that influenced the start of the Industrial Revolution. Climate Change is a 'recipient of change' through such elements as emissions generation and has the capacity to become a 'generator of change' through adverse global climatic conditions with catastrophic possibilities.

[21] Mitcham (1994): technology is not a univocal term; it does not mean exactly the same thing in all contexts. It is often, and in significant ways, context dependents – both in speech and in the world. Ofori (1994) defines technology as the "application of science to production, which also includes construction. It embraces techniques, processes, materials, machines, tools, information, the building themselves during the course of production and, ultimately their subsequent use. McGuinn (1978): What is Technology? Technology is a form of human activity (comparable to science, art, religion and sport) with the key characteristics of this activity (1) has material output, (2) fabricates or is constitutive of those outputs, (3) is purposive, (4) is resource based and resource expanding, (5) utilizes or generates knowledge, (6) is methodological, (7) takes place in a socio-cultural-environmental context, and (8) is influenced by individual practitioners' mental sets.

The development of technology (McGuinn 1978, 1991; McLoughlin 1999) can be characterized by increasing productivity of labor and capital, new products to satisfy demand (needs and or wants), better conditions in construction, improved quality (Faulkner et al. 2000), usability, durability and recently by increased protection of the environment, and conservation of resources to ensure sustainable growth.

The conservation of resources generally requires smaller energy consumption (footprint, EEA 2005) and a reduction in the amount of materials such as steel, cement and timber used (dematerialization). All such trends, according to Sebestyén (1998), "*ultimately make economic sense if they improve performance: that is, if they result in cheaper buildings of better quality with greater durability*." What is the potential magnitude of that these initiatives and would they be able to contribute substantially to addressing the challenges?

However, technology[22] is only one variable of the proposed solutions that because of the magnitude of the challenges will involve social and cultural changes, radical paradigm shift, and possibly affect the 'way of life,' the 'messy' ingredients of the solutions.

Pointedly, the Club of Rome publication "*The Meadows Report"* (Meadows, 1972) observes that technological progress cannot be expected to ensure sustainability, including safeguarding resources and protecting the environment without some massive global initiatives that are not in the horizon. If technology, as in the Meadows Report,[23] can not be expected to ensure sustainability, what can be expected from technology when the forces of population growth/demographics and environmental/climate change[24] issues add their demand to the

[22] Ellul (1954) thesis: "technology is the autonomous and defining characteristic of modern society."
[23] Up to relatively recently, technology was seen as knowledge to transform humanity and nature for the better, to free man from the limitations on his powers that were once accepted as inevitable.
[24] IISD, 2005b reports that "The head of the G8 governments, meeting in July 2005, called it a 'serious and long-term challenge that has the potential to affect every part of the globe.'

industry? Those that study, understand, know the implications of change, and prepare to implement the best change patterns and paradigms will survive; the others may become yesterday's breadwinners, downsizers and even failures.

The nature and magnitude of the environment, sustainability and waste issues as approached by the Club of Rome (dynamic network model where the units of flow are merely the material flows) appear as incomplete. A more clear definition of the nature and type of these issues are needed to determine if the long term trend of manufacturing industrialization, as currently perceived or the capacity of a fragmented industry (Gann, 1996; Pike 2002; Woudhuysen and Abley 2004; Carassus 2004), are adequate to meet those challenges, if indeed they are the challenges that have recently moved from 'wants' to 'needs' in an increasing and alarming level of criticality.

Because the industry, even at a global scale, is hard to consolidate and concentrate, there are opportunities for differentiation considering that knowledge (human and technological) is a formidable strength. However this requires knowing where to find the mechanisms for change and implementing them effectively and efficiently. Large international companies, capable of mobilizing resources at the needed scale, may be the most appropriate actors, other than governmental intervention such as the Marshall Plan, to implement the massive global initiatives alluded to in the Meadows Report (1972). But first we have to identify the biggest polluters[25], the highest consumers of resources and their propensity to scarcity as well as the industry's mechanisms and capacity for change in the context of the systemic nature of the building construction industry.

[25] Pollution defined as any alteration of air, water or soil that harms the health, survival and activity of humans and other living organisms (Raven and Berg, 2004).

This dissertation may serve as catalyst for thought and reflection on the signs of the times, the economic opportunities in meeting the challenges as well as understanding the industry's systematic nature and its capacity for change.

1.1.3 Critical Planners (philosophers, think tanks, global strategists, academicians)

The United Nations forum on *"Our Common Future"* (The World Commission on Environment and Development, 1987) defines sustainability: "*Today's needs should not comprise the ability of future generations to meet their needs*". However, as previously mentioned, sustainability and the environment/climate change are components of a larger framing of the challenges exacerbated by the substantial doubling of the global population within less than one generation and a concerted move by nations with major population to move towards a higher standard of living. Understanding that larger frame may require going beyond the policy maker and Executive, into a think tank of academicians and critical thinkers that can bring into focus the synergy of the challenges.

At The Fifth International Postgraduate Research Conference at the University of Salford in Manchester UK, when presenting the topic of this study (Fernández-Solís 2005), one Ph. D. student from Malaysia asked if there are any think tanks dealing with this subject. Literature search indicates that at the present time, there are no publications addressing the concatenated subjects of the challenges and how they impact the building construction industry as outlined in this study. This presentation was awarded "*the most innovative idea in the human and built environment*" certificate in that conference! Current research trends, as illustrated through literature search as mentioned, is not addressing the questions as proposed in this study. For example:

1. Research by think tanks and scientists on global warming exists. Global warming is a reality surrounded by theory. The measurement and analysis of the global warming rate is a source of controversy. Even the role of water vapor in global warming is fiercely debated: "*It is the wild card in the whole greenhouse story*," notes university of Michigan geochemist Philip Meyers. As the global thermostat rises, it causes more water to evaporate. Some models predict that added humidity would counteract the heating effects of greenhouse gases; others predict that it could amplify the gases' warming effect, another Axel enigma.

Other metrics, such as the global carbon emissions[26] from fossil fuel burning, have greater acceptance among scientists like the Scripps Institution of Oceanography, the Lawrence Livermore National Laboratory, and the American Association for the Advancement of Sciences. Michaelowa and Lehmkuhl (2005) state: "*One and a half decades of climate negotiations have directly caused reduction of greenhouse gas emissions of about 150,000 Tons of CO_2. At prevailing market prices, making the full negotiation process greenhouse-gas-neutral is valued at approximately US$0.5 million, which is a fraction of the cost of the conferences*." A new industry of trading credits for gas emissions has sprung in response to attributing some cost to common goods, the atmosphere. However, the possibility of Carbon Trading becoming a sustainable global solution to the real problem is an open question.

What is the real problem? Global CO_2 emissions in 2003 were 6.8 Gigatons (Fichtner et. al. 2003) and this amount jumped to 28.0 Gigatons[27] with a t_c (see *Table 1.2 Doubling Time*

[26] Global CO_2 levels rose from 315 ppm in 1958 to 370.9 ppm in 2001 (Raven and Berg, 2004) attributed to the burning of fossil fuels (coal, oil and gas) and the clearing or burning of forest (human activity). According to Sebestyén, (1998) during the last Ice Age (20,000 – 40,000 years ago) the levels of CO_2 were at 180 ppm; in 1800 they were 280 ppm. The year 2005 has seen readings of 380 ppm and current projected estimates have a range of 500 – 550 ppm by 2050 (Ken Caldeira of Lawrence Livermore), a range that we may be approaching much sooner than expected. At the current rate of emissions (pre 28 G-tons findings) predictions were for a level of 650-700 by 2100.

[27] Ken Caldeira, atmospheric scientist of Lawrence Livermore Laboratories, California.

Equation) of 1 in 2005, a sobering piece of data considering that the exponential growth is predicted to continue for at least a decade and the effects on climate change are predicted to last in the hundreds if not thousands of years. The jump to 28 Gigatons has not shown in ppm readings, currently under analysis as of this writing, and need hard verification. According to Speth (2005) "*the current system of international efforts to help the environment simply isn't working. The (current) design makes sure it won't work, and the statistics keep getting worst.*" The Council on Environmental Quality and the Department of State prepared a report (USCEQ, 1980) on "*probable changes in the world's population, natural resources and environment through the end of the Century*" signed by four distinguished American scientists – David Keeling, Roger Revelle and George Woodwell in addition to Gordon MacDonald (Woodwell et al. 1979).

Who says there is a problem? The report predicted in 1979 states "*a warming that will probably be conspicuous within the next twenty years*." "*In recent decades the concentration of carbon dioxide (CO_2) in the atmosphere has been increasing in a manner that corresponds closely with the increasing global use of fossil fuels*." According to sources quoted by Speth (2005), nine of the ten hottest years since record keeping began have occurred since 1990.

So what is the criticality of this problem? Scientists at the Wood Hole Oceanographic Institution believe that the most likely mechanism for abrupt climate change is disruption of ocean currents, such as the Gulf Stream (Gagosian, 2003; Broecker, 1997; Epstein and McCarthy, 2003). This is an event with precedence according to fossil records, when the Gulf Stream has shut down quickly in the past, plunging the North Atlantic region into dramatically cooler era. With the ending of the Little Ice Age in the 1700's (Landes 2003, see Appendix F), there is a greater concern in Europe than in America of the consequences of these trends.

However, America is not spared since this is an event with global implications. Today's computer models according to Speth (2005), suggest that a shutdown of the Gulf Stream would produce winters twice as cold as the worst winters on record in the eastern Unites States. The possible and probable cause of this is the Global warming that melts the northern ice caps causing dramatic increase in freshwater released into the North Atlantic, an event well under way. According to the Woods Hole scientists (Gagosian, 2003) it is "*the largest and most dramatic oceanic change ever measured in the area of modern instruments*." Current international efforts are trying to set a cap not to exceed concentrations of 450 – 500 ppm of CO_2 but the rate of increase is quickening, the doubling time (t_c) is decreasing.

The National Academy of Sciences (NAS) Climate Research Board concluded: "*If carbon dioxide continues to increase, the study group finds no reason to doubt that climate changes will result and no reason to believe that these changes will be negligible. However, the great and ponderous flywheel of the global climate system may be expected to slow the course of observable climatic change. A wait-and-see attitude may mean waiting until it is too late*." The doubling of the CO_2 content in the atmosphere could be expected after 2050 with the results of significant alterations of precipitation patterns around the world, and a 2 – 3 degree Celsius raise in temperature in the middle latitudes of the earth (NRC, 1979). By the 1980's the United Nations Environment Programme, the Worldwatch Institute and the National Academy of Sciences were saying much the same thing.

The U.S. Energy Information Agency (as quoted in Speth 2005) projected that CO_2 global emissions will increase by 60% between 2001 and 2025, and the Paris–based Organization for Economic Cooperation and Development estimates that its members' CO_2 emissions will go up roughly a third (33%) between 1995 and 2020. However, a doubling has occurred from 6.8

to 12 Giga tons in one year (2004) and another doubling from 12 to 28 Gigatons has occurred in one year (2005), making the NRC 1979 prediction more ominous. The probable cause of this increase (as it relates to new building construction) is treated in the following chapters. However, for the record it is estimated that human activity can account for approximately 9.5 Gigatons the balance is now attributed to methane emissions from the thawing of the tundra of the world, areas of frozen carbon sinks that have been frozen for millions of years (Kluger, Time 4/3/06; Daneshkhu and Harvey, FT 2/3/06; Simon, FT 4/7/06). If this is the case, we are witnessing a secondary effect of global warming that is now independent of artificial generation of CO_2 emissions. In other words a threshold appears to have been crossed, a mechanism has been set in motion that is even harder to contain and for which we now must account in our preventive or corrective measures.

2. Research by think tanks and scientists on the environment and sustainability in relation to the industry is ongoing. LEED® (Watson 2001), BREEAM™, HQE^2R, and GBTool™ (Cole 2002; Cole and Larson 2002; Epsten and Larson 2002) are examples of models in action. A new industry of LEED certification has sprung which is adding insight, effort and enthusiasm towards ecological solutions. There are approximately 1,800 projects that have some sort of LEED certification, among the hundreds of thousands project that are built annually. Leading to question is this a sustainable solution with the capacity to reach the needed scale and magnitude in the future? The same question applies to all the green, high-performance, environmental and sustainable initiatives. Is the magnitude of the effort able to reach the scale of the problem?

3. Although human impacts on the environment are difficult, multifarious and complex to assess, biologist Paul R. Ehrlich (1969) and physicist John P. Holdren in 1970 (Holdren

et al. 1973) developed the formula I = P * A * T with the factors of number of people (P), the affluence per person (A) as a measure of the consumption[28] or amount of resources used per person and the environmental effects (resources needed and waste produced) of the technologies used and resources consumed (T), also known as transformation (resources, energy and waste) to show the relationship between environmental impacts and the forces that drive them. If any of the factors change, the equation changes and may be thrown out of balance. Furthermore, current science does not fully understand the scope of the individual factor, as each one is extremely complex. As science progresses, we become more certain of the actual impacts of pollution[29].

Jane Lubchenco (1998), President of the American Association for the Advancement of Science, observed "we are modifying physical, chemical and biological systems in new ways, at faster rates, and over larger spatial scales than ever recorded on Earth. Humans have unwittingly embarked upon a grand experiment with our planet. This brings us Ellul's (1954) philosophical observation: "*The bet or wager of the Century is not some unqualified conquest of nature but the replacement of the natural milieu with the technical milieu. The modern gamble is whether this new milieu in contrast with the natural milieu will be better or even possible*."

The outcome of this experiment is unknown, but has profound implications for all of life on Earth. We know little about the cumulative, long-term consequences of all chemical exposures on people (Carson 1962). We know even less about what the Chemical Revolution has done to natural systems. As Palmer (2004) elucidates, the interface of the two meta-systems

[28] Consumption is used in this study as the human use of materials, services and energy in an economic and social (life style) act. Sustainable consumption is the use of goods, services and energy that satisfy basic needs and improve the quality of life but also minimize the use of resources so they are available for future generation. Basic needs are defined further on in this study.

(natural and artificial) is complex and there is a lack of an ontic and ontological framework to frame the issues. According to the NAS aforementioned report, "*Global warming could well have serious adverse societal and ecological impacts by the end of this Century, and temperature and sea levels could also continue to rise well into the next Century even if societies stabilize the levels of greenhouse gases in the atmosphere*."

The scientists with the International Geosphere-Biosphere Program state: "*The evidence is overwhelming that [rising temperatures] are a consequence of human activities…We are now pushing the planet beyond anything experienced naturally for many thousands of years. The records of the past show that climate shifts can appear abruptly and be global in extent, while archeological and other data emphasize that such shifts have had devastating consequences for human societies. In the past therefore, lies a lesson*." Can a framework for a better understanding of the interface of the artificial and natural meta-systems be created?

4. The ecological footprint[30] of the developing nations (Venetoulis and Talberth 2005) is small (India 1.0 hectares or 2.5 acres) whereas the footprint of the developing nations is relatively large (USA 9.6 hectares or 23.7 acres) numbers that are surpassed with each passing day. As developing nations add population, and large numbers of the population move from developing to developed status, the overall footprint of consumption increases substantially. Thus affecting resource consumption and waste generation globally (Barr 2004) , a subject that brings to light the issues of this study and the impact of building strategy and activity (See *Fig. 1.1 and 1.2).* According to Speth (2005), "*collectively the environmental impacts of rich and*

[29] Pollution, according to Speth (2005) is harmful – too much of something in the wrong place. For example CO_2 naturally in the atmosphere helps keep the earth warm enough to be habitable, but the build-up of vast quantities of excess CO_2 now threatens to alter the planet's climate and disrupt both ecosystems and human communities.

[30] Ecological Footprint concept was developed by Mathis Wackernagel and colleagues (1997) Universidad de Xalapa, Mexico (referenced by Raven and Berg, 2004). In this study each person has an ecological footprint which

poor countries have mounted as the world economy has grown, and we have not yet deployed the means to reduce the human footprint on the planet faster than the economy expands." How is sustainability affected by the cumulative increases in the ecological footprint? What happens when the major populated countries achieve the same or greater footprint levels than that of the United States, Japan or the European Union?

5. Within the last twenty years, the construction industry has undertaken numerous research initiatives to identify and improve productivity and processes (Bennett et al. 1998a). This research at the frontier of science for the building construction industry includes: Organization, Performance, IS/IT, Codes and Standards, Fees and Structures, Environment, Ecology, Sustainability, Economy and Facility Management Related. Is this research addressing the forthcoming challenges?

6. 'Knowledge,' for the international company executive is indeed a formidable force. Some knowledge and ideas become creations, others innovations or improvements on the creation, others adapt or transfer some technology or process to a whole different product, system or industry. With exponentialoid challenges to industry, resources and emissions there should be exponential increases in ideas, and knowledge, like the doubling of chip capacity every two years according to Moore's Law.[31] However, when was the last time that building height doubled? Or when was the last time that the strength of primary structural materials such as concrete and steel doubled?

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is the average amount of productive land and ocean (in hectares) needed to supply that person food, energy, water, housing, transportation, and waste disposal, see EEA 2005.

[31] Gordon Moore (Service, 2005) projected in 1965 (forty years ago) that the number of transistors on a computer chip would double every two years. Today Intel's high end chip contains more than 1.7 billion transistors, and that number is expected to exceed 12 billion by 2012 (Service 2005).

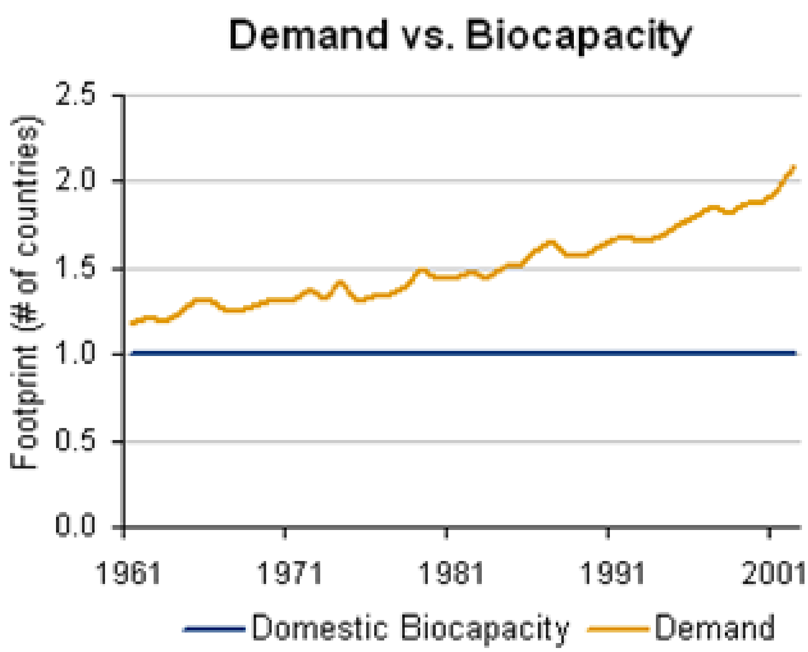

Fig. 1.1 Footprint - India

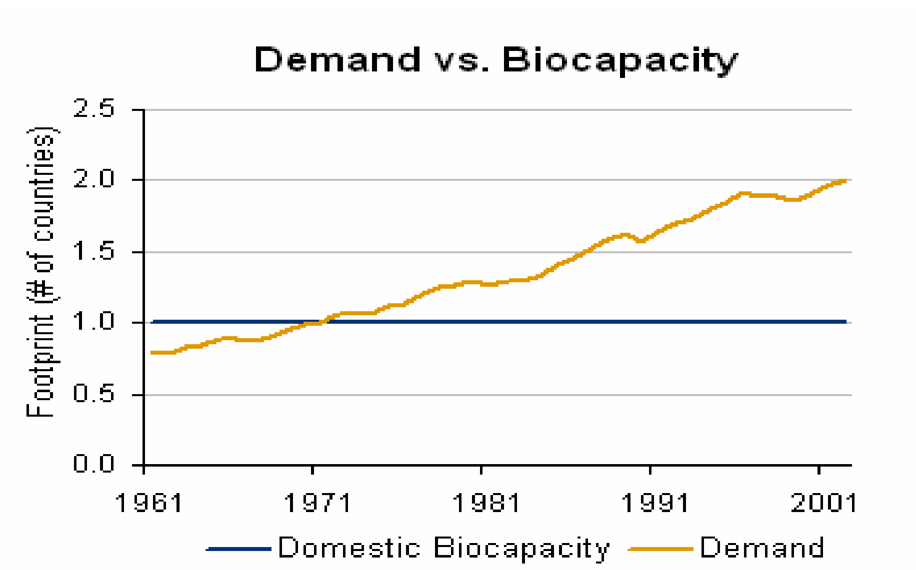

Fig. 1.2 Footprint - China

An industry that is compelled by a necessity to exponentially increase the effectiveness and efficiency in the use of raw materials, or in new types of materials or in some other form substantially dematerialize, would be on the right path towards sustainability and waste reduction. To achieve this, the construction industry, a bastion of tradition and stability, needs a new paradigm where critical planners, think-tanks, global strategists, academicians, public and private institutions are substantial contributors. A one thousand meter habitable building may not end up being a luxury but a driver towards the new technology in materials, methods and processes that are not even thought of at this point in time. It is the cauldron of ideas, visions, imagination and desire waiting for the right time and moment to become real.

7. Mitcham (1994) comments on the Historical Traditions in the Philosophy of Technology: "*What is seldom noticed within the Historiographic discussions, however, is the extent to which histories of technology nevertheless fail to address certain key philosophical issues. Indeed from the perspective of philosophy, what is needed is what may, for want of a better phrase, be referred to as a history of ideas about technology - that is, the study of how different periods and individuals have conceived of and evaluated the human making activity, and how ideas have interacted with technologies of various sorts*." Durbin (1987) agrees that the urgent problems connected with technology require philosophical clarification since "*much that has been written about these problems is inadequate – making it all the more important for serious philosophers to get involved*." And why philosophers instead of scientists, practitioners and academicians should get involved? Kuhn (1962) observed that in a pre-paradigm situation, a paradigm shift, or in a crisis, the professions resort to philosophy (Thompson 1993; Titus et al. 1995) for clarity of ideas and then to science and technology for implementation.

This dissertation analyzes different periods, individuals and technologies that have been conceived and applied in the limited arena of building construction, from a philosophical perspective, to determine the systematic nature of the industry. This study in turn may shed some light on the systematic nature of ideas in general from a historical narrative as above posed by Mitcham (1994).

8. Furthermore, the fact remains that according to some, there is not a theory of building construction and a questioning of the structural direction of the industry bias towards mechanization and industrialization. Which brings us back to the original premise of this study: are we asking the right questions? Where is all this research leading? The answers to these questions imply having a framework for analyzing them. This study purports to frame this query through our hypothesis:

> A better understanding of the systemic nature of the building construction industry is needed to reason about its capacity to change in the face of critical challenges.

This study's better understanding of the systemic nature of the industry builds from a philosophical, systemic thinking, up to the discussion of a purely theoretical view of Schemas that assists in framing the query: Can we come up with a theory for understanding the systemic nature of the industry, its current paradigm, its mechanisms for change and possibly create the framework for a theory of understanding the building construction industry?

Critical planners will benefit from this study by helping them understand a framework of the industry's theoretical base, proposed in this study, so we can better manage the challenges that are here and those that are coming. This study may serve as a springboard towards developing a theoretical and practical body of knowledge (such as a proper theory of the building construction industry), a pre-paradigm.

1.2 METHODS OF ANALYSIS

The nature of this study begs a meticulous definition of a method of analysis, a description of the choice of the unit of analysis, the origin of the data, and how is the data analyzed. The following general areas as the topics of interest are in this study: (1) Challenges, (2) Systemic nature of the Industry, and (3) Change Mechanisms / Capacity for Change, require differing methods of analysis.

The areas of concern for this study have an unprecedented complexity[32] and uncertainty[33]. This study claims that classical modelling – representing the factors and relationships mathematically (Gödel 1931) are not applicable based on the following reasoning. Problem Structuring Methods (PSM) by Rosenhead and Minges (2001), state that the most demanding and troubling task is to decide what the problem is. Usually, there are too many factors, many of the relationships are unclear or in dispute; and most importantly, they do not reduce naturally to quantified form. The statement that classical modelling is not applicable will be a lighting rod and merit further elaboration, albeit premature, but we feel serve well in understanding where we are coming from and how we frame the issue:

Population dynamics uses a mathematical language without further a refined identification of the causes or forces behind that dynamic. For example, behind a logarithmic population growth we have a pure mathematical language based on a final growth rate that considers the net of the rates of growth and death without regards to the causes or forces behind. By causes or forces, we do not mean what caused the birth or the death but the social, cultural,

[32] Complexity because of an environment populated with dense interconnections that have not been studied.
[33] Uncertainty because (borrowing from Hopwood 1980) the consequences of human action and the objectives of that action are largely indeterminate at this point in time.

political, religious, scientific, etc that are forces that directly and indirectly affect numbers of birth and death. When we try to integrate these causal forces to either rate of growth or rate of death, we add a level of complexity based on the worldview that frames the links.

The algorithmic model of exponential growth regarding population integrates life and death but fails to integrate the historical forces behind that life and death such as medicine, hygiene, the advent of potable water, advances in agriculture etc.

Our fascination with science and the numerical symbolic language (that includes most of our analytical arsenal, strong part of our current paradigm) has obscured the link of the next level of forces that affect life and death but are hard if not impossible to interpret with numbers because a main ingredient is qualitative in nature. The central point of this criticism is that it takes a different worldview, a different paradigm to look at the forces behind the primary forces, a concept encapsulated in systems and meta-systems or systems of systems, a different frame, a different philosophical outlook on its way of codification into theories, theorems, hypothesis etc.

In our estimation, a pre-paradigmatic, philosophical dissertation, such as this one looks at the questions behind the questions behind the questions, behind the question, as far as we are capable. Then we reach the barrier of nature and extend our hand into 'that' virtual wall (Heidegger) to find what nature reveals that we can interpret with our different languages (verbal, numeric, symbolic, etc…-Popper). In the case of population numbers, we have gone one level of integration. This is not a detrimental criticism but merely stated that there is more, although it has waited until we have a better understanding of complexity to hint at its existence and pose the possibility of the existence of a next level of integration. These new levels of questioning, of integration, sometimes affect the reining paradigm and create the turbulence of an undefined condition where there is not science but proto-science, what some call 'mere' philosophy.

This dissertation is an encouragement to use the philosophical tools for seeing the exponential as a first level integration-like of life and death, rates of birth and death in algorithms, and the complex forces as the next level integration-like where the kind of forces are vectorials rather than algorithmic. In this worldview, the vectorials components integrate both the hard system quantitative and the soft system qualitative, into forces that have different sources as well as characteristics. In other words, first level integration, algorithms, produce an exponential, and second level integration, vectorials produce an exponentialoid. This, by the way, may open the way for additional levels of integration, unforeseen in this dissertation which merely hints at the possibility of its existence.

Softening the wording when talking about the great contributions to knowledge that first order thinking and worldviews have provided may water down the punch needed to generate debate. According to Kuhn, sometimes it takes strong wording to jolt out of a paradigm the deficiencies that for long time have inadvertently obscured a deeper view. There is no doubt that the strong wording will precipitate critical debate, but that is welcomed and inevitable, a part of the crisis that paradigms go through in the process of evolution.

Model representations and multiple explanatory applications used in this study to frame the issues and provide enough structure so that those who must take responsibility for the consequences of the choices that are made (the afore-mentioned stakeholders) do that on a coherent basis with sufficient confidence on the data, the information, and the findings to make the necessary commitment. If a theory, according to Kuhn (2000) like Newtonian mechanics, had only a single application (for example, the determination of mass ratios for two bodies connected by a spring), then the specification of the theoretical functions it supplies would be literally circular and the application correspondingly vacuous. However, from Sneed's viewpoint (as quoted by Kuhn 2000), no single application yet constitutes a theory, and, when several applications are conjoined, the potential circularity ceases to be vacuous because it is distributed by constraints [34]over the whole set of applications.

PSM methods are modest because they do not set out to capture a single truth about the situation from which the one best answer can be derived; and more ambitious because their aim is rather to provide useful assistance to those processes of dialogue and debate which prepare the way for decisions that significantly affect future prospects. Several renowned authors in PSM address this dichotomy:

Ackoff (1974, 1979a)[35] states that problems are abstractions exacted from 'messes' by analysis. Problems may be solved; messes need to be managed. For Rittel and Webber (1973a and b) a "tame" problem is one which can be specified, in a form agreed by relevant parties, ahead of analysis, which does not change during the analysis. "Wicked problems by contrast, have many alternative types and levels of explanation of the phenomena of concern, and the type of explanations determine the nature of the solution." In summary, a wicked problem is one for which each attempt to create a solution changes the understanding of the problem. Wicked problems cannot be solved in a traditional linear fashion (Syben 1993) because the problem definition evolves as new possible solutions are considered or implemented. According to Rittel and Webber (1973a and b), virtually all technology-related projects these days, are about wicked

[34] Sneed (quoted by Kuhn 2000) calls constraints lawlike restrictions that limit the structure of pairs of sets of partial models rather than individual ones. When applications are tied together by constraints, they prove capable simultaneously of specifying the manner in which theoretical concepts or terms must be applied and on the other hand some empirical content of the theory itself.

[35] Ackoff's (1979a) characterized OR as "mathematically sophisticated but contextually naïve. Academic OR has been dominated by the search for computable methods that can 'solve' bigger problems, or solve problems faster, or for novel formulations that can cast recalcitrant problems in a shape that allows optimization to be performed. OR connotes in this study hard systems.

problems. Decision may be made after the “wicked” problem has been “tamed,” which portrays the position taken in this study. Tamed problems in contrast have the following characteristics:

- Relatively well-defined and stable problem statements
- With a definite stopping point. That is, we know when a solution has been reached
- A solution can be objectively evaluated as being right or wrong
- Belongs to a class of similar problems which can be solved in a similar manner
- The solutions can be tried and abandoned
- Comes with a limited set of alternative solutions.

Schön (1997) posses a very interesting question in the following statement: “problems of the high ground tend to be relatively unimportant to individuals or society at large… therefore shall we descend to the swamp of important problems and non-rigorous inquiry?” Schön thereby summarizes the approach to this study.

Ravetz (1971) also states that technical problems are those for which at the inception of the study there exists a clearly specified function to be performed, for which experts can seek best means. For a practical problem, by contrast, there will exist (at most) some general statement of the purpose to be achieved. The output then consists on an argument in favour of accepting a particular definition (or framing) of the problem, together with its implication for the corresponding means of solutions to be adopted.

Checkland (1978, 1981, 1985) distinguishes between what he calls hard and soft systems thinking. Hard systems thinking assumes that the world consists of systems that can be objectively modelled (Fowler, 2003; Zemke 2001); that there are well-specified and agreed objectives or goals; and that its main task is to determine the most effective or efficient means to realize those goals. By contrast, soft systems thinking accept that the rich complexity of the world cannot be assumed to consist of systems, which can be modelled, let alone optimized.

Rather, systems concepts can be helpful in structuring our thinking and learning about problematic situations and we should aim for debate and accommodation about the nature of the problem, rather than its solution.

Conceptual analysis attempts more than simple analysis (Mitcham 1994). In this sense, thinking is not so much a linear deductive process as a recursive procedure. Each part thus takes either its historical or its analytical approach, but then circles the topic as a whole in its own particular plane of reference taking in both aspects.

This diverse analysis is pointing in the same direction. Problems for which there are uncontested formulations that can be specified in advance are susceptible to technical solution. But different methods, incorporating the engagement of human judgement[36], and heuristics such as those discussed in this study, are needed to make progress for which these simplifying assumptions are invalid. Schön (1997), in the above quotation, assumes that any investigation in this 'swampy' terrain must be non-rigorous. However, it may be argued that in the more demanding and more important conditions of the swamp, some kind of appropriate yet systematic approach is still more crucial. What is needed, and the aim of this study, is to find a re-specification of rigor that is appropriate for the subjects at hand, "the problems of greatest human concern." The nature of the situation itself is the objective of this study[37]. When the words 'wicked' are mentioned, the reader should keep in mind what we have identified in this section.

The following systematic approaches are applicable to the subjects of this dissertation.

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[36] Evaluating theories is to determine whether or not they correspond to an external, mind-independent world. Judgments of this sort are necessarily comparative: which of two bodies of knowledge – the original or the proposed alternative – is *better*. Nothing about the rationality of the outcome of the current evaluation depends upon their, in fact, being true or false (Kuhn 2000).

1.2.1 Method of Analysis of the Challenges

Population, sustainability and environment degradation, among others, form the complex forces that "push" the industry into an uncertain future. These challenges originate from the natural environment's internal embedded factors such as population growth, and increase in standards of living and environmental climate change,[38] as well as external factors such as depletion of natural resources (by a growing building construction industry – 30-50% of most nations GNP.[39])

Population rate of growth appears to be coming under control; however run-away increases in global affluence, environmental issues and depletion of natural resources remain unchecked although there is a growing concern and action regarding emissions. The artificial environment is considered, by some, that once created have a life of its own and control is lost. For example: According to Heidegger (1954) "*Once technology (an external factor to the natural environment) has been created, and is further fueled by a real demand,* (it – technology) *will never be allowed to be overcome by human beings*." "*The solution to the problems of technology is not less but more and more comprehensive technology*" (is a common saying, as quoted by Mitcham 1994).

Specifically, **Challenges** are investigated by using:

- Multiple sources of evidence
- Multiple explanatory applications

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[37] Flood and Jackson (1991) and Mingers (2000) elaborated a scheme (System of Systems Methodology) for selecting the best method based on two dimensions of problem situations, allowing the nature of the situation itself to be the object of systems study.

[38] The earth warming theory may have a real basis considering that the years 1980 to the present are the warmest years in world-wide weather record, with 1998 being the warmest (Raven & Berg, 2004). Sebestyén, 1998 states, "At present, it is neither nature nor the cosmos that is the principal cause of change. Rather it is mankind itself, and the projected climate warming over the coming Century will be greater and more abrupt than any natural climate variation since the dawn of civilization."

[39] Raven & Berg, 2004.

- Theoretical propositions, rival explanations

For example, the measure of change is related to the time constant for doubling the unit count on the system of interest such as the t_c of population, t_c resource depletion and t_c waste/pollution generation. This information which is readily available from library sources as well as the internet provides the foundation of the magnitude and direction of the forces that challenge the building construction mechanisms for change.

An example is the t_c the population characteristics of Sri Lanka:

Exponential Growth Example

The prediction that Sri Lanka doubles its population in 53 years is based on:

- The assumption that ***r*** will remain unchanged (which is surely false)[40]
- The mathematics of exponential growth.
- The product of growth grows itself.

The growth of populations is a problem in compound interest: next year's population = (current population) + ***r*** (current population). At the end of each year (or whatever period is chosen to use), the base against which the rate is applied has grown. Whatever figures are picked, as long as ***r*** is positive, a plot of population as time elapses will produce an exponential growth curve. The rate of population growth at any instant is given by the equation in Table 1.1.

The exponential function $y = Aa^x$, also known as Euler's formula, is a continuous function and is represented by a continuous curve with an accelerated slope (up or down).

Another important aspect that highlights the growth rate is the doubling time. In other words, how long will it take for a quantity to double, and it is calculated as shown in Table 1.2.

[40] Birth rate (*b*) − death rate (*d*) = rate of natural increase (*r*). A fuller treatment of this issue will be presented later.

Table 1.1: Exponential Growth Equation

$$\frac{dN}{dt} = rN$$

Where

- d (Δ) is the delta
- ***r*** is the rate of natural increase in
- ***t*** — some stated interval of time, and
- ***N*** is the number of individuals in the population at a given instant.

The algebraic solution of this differential equation is $N = N_0e^{rt}$ where

- N_0 is the starting population
- ***N*** is the population after a certain time, ***t***, has elapsed, and
- ***e*** is the constant 2.71828... (The base of natural logarithms).

Plotting the results gives this exponential growth curve, so-called because it reflects the growth of a number raised to an exponent (***rt***).

Table 1.2. Doubling Times Equation

When a population has doubled, $N = N_0 \times 2$.

Putting this in our exponential growth equation,

$2N_0 = N_0e^{rt}$

$e^{rt} = 2$

rt = ln (natural logarithm) of 2 = 0.69

doubling time, $t = 0.69 / r$

So Sri Lanka with an ***r*** of 1.3% (0.013) has a doubling time
$t_c = 0.69/0.013 = 53$.

Population has two aspects (Ehrlich 1969): First is the aspect of the numbers, which are an estimate, derived from the population rate of natural increase (which is composed of estimated births and death rates). Second, this study uses the transition or migration of a population set from developing to a developed state, which is an even more uncertain estimate. In the orthodox paradigm of OR, the answer to uncertainty is *probability*.

Where there is lack of certainty about a future value of some factor of interest, the indicated OR action is to drive a probability distribution across its possible values. Data is not available from previous experience in comparable circumstances, thus subjective probabilities – of how likely the events of interest are felt to be – may be elicited. However, according to Rosenhead and Mingers (2001), neither objective of subjective probabilities can be central to the framing of the problems of the 'swamp.' "*Indeed, if either version is applied to swampy problems, the resulting clarity is likely to be achieved at unreasonable cost.*"

Where the uncertainties are integral part of the 'wickedness' of the situation, attempts to reduce them to numbers can only result in the analysis being unhelpful. In this respect subjective probabilities are more dangerous because they can appear to offer quantified knowledge of the future in areas where repetitive observations (perhaps any observation at all) are lacking.

> "*As a general guide one could say that probabilities are likely to be a primary aid to choice only when what is at issue is of less than compelling importance. When an eventuality whose occurrence is uncertain (and) is important enough to be considered in deliberations, it is that possibility that is relevant, more than any numerical expression of its probability. It follows that methods for wicked problems cannot employ probabilities, since the implications of those possibilities cannot be dismissed from consideration*." Rosenhead and Mingers, 2001.

Accordingly, a more appropriate approach is the use of scenarios as a way of embracing different possible futures within a study. A number of contrasting pictures of the future are developed. Each tells a coherent story, in words and diagrams, as well as numbers, of how the relevant population environment and migrations might evolve. Placing alternative future scenarios is a way of opening up discussion about threats and opportunities. Predicting the future may lead to erroneous conclusions. Even great scientists can misread the future and have done so on many occasions. According to an old Arab proverb (quoted by Sebestyén, 1998), 'he who predicts the future lies, even if he tells the truth.' With this in mind, we shall be cautious about predictions and also about issues concerning the twins of evolution and progress whenever they are at the threshold of innovations.

1.2.2 Method of Analysis of the Systemic nature of Building Construction

The building construction industry is studied through evolution of the building generation process embedded in the final product. Although the generated output, the built environment, reflects the industry, in and by itself it does not readily reveal the forces that have created it. The generated objects mostly reflect the breeding ground of ideas, theories, technologies and values (Saxon 2005) that existed within this amorphous fragmented industry (Gann, 1996; Pike 2002; Woudhuysen and Abley 2004), called building construction, at a point in time, reflecting the state of the art heuristics.

Kuhn (1962) observed the difficulty in isolating the components of the generative process by regarding individual inventions and their cumulative process:

> "*The same historical research that displays the difficulties in isolating individual inventions and discoveries gives ground for profound doubts about the cumulative process through which these individual contributions to science were thought to have been compounded*."

Mitcham (1994) analyzed the generation process from philosophical and technological perspectives. For the purpose of this study we adopt, McGinn (1991) 'characterology[41]' of technology with six key aspects or components of human activities, especially those involved with Technology, such as building construction, are: inputs, outputs, functions, transformative resources, practitioners and processes. In McGuinn's typology an artefact (a building in our case) is the outcome of technology, but not itself technology. Stephen Kline's (1985) response to the same question "What is Technology?" recognizes four definitions of technology: as artefacts or hardware; as sociotechnical systems of production; as technique or methodology; and as sociotechnical systems of use. Kline recognizes both making and using as technological activities, and grants that artefacts can be termed technology. However, McGuinn does not accord artefacts the full status of technology.

In this dissertation, technology, social, economic, cultural, and other values are embedded in the product, the building. In this sense, we acknowledge Kline's understandings of the product containing technology; however, we adapt McGuinn's typology[42].

In the alluded words of Peters (1986) we have as an output the "product" containing, embedded, the "inputs, functions, transformative resources, practitioners' contributions and processes" of its creation, thus making invisible the generation force that this study purports to discover, in order to shed light, post facto, on the historical mechanisms for change.

Furthermore, we are dealing with both the natural and the artificial world. Most puzzles in normal science are directly presented by nature and according to Kuhn (2000) all involve nature indirectly. Miss Masterman, critiquing Kuhn, underscores that paradigm 'can function when the theory is not there'. In fact, a paradigm is an artifact, which transforms problems to

[41] This 'characterology' of technology can be traced back to Ellul (1954).
[42] Carpenter 1974, quoted by Mitcham 1994, differentiates among technology as object, as knowledge and as process. However process is termed for connoting repetitive operations, routine performances.

puzzles and enables them to be looked at and eventually solved, even in the absence of an adequate body of theory. In his latter years Kuhn (2000) concedes: "*paradigm is what you use when the theory isn't there*." If indeed building construction has no theory, as Koskela (2002) states, then we must identify the current building construction's paradigm.

We make the claim that the building industry's response dynamics are largely unknown as they are governed to a large extent by systemic mechanisms of change embedded in the building 'industry.' The building industry has porous, dynamic boundaries with the economy, society, and culture.

Different techniques must be used for the study depending on the area of investigation. Mechanisms for Change and Change Trends may use:

- Multiple sources of evidence
- Multiple explanatory applications
- Theoretical propositions, and rival explanations
- Exploring possibilities and options
- Causal Loop Analysis (Soft Systems Analysis, Systems Dynamic Modelling)
- Popper 's (1972) method of Conjecture and Refutations
- Pattern matching

Comprehensive Literature reviews consisted in searching libraries, the Internet, journals and publications for the areas of knowledge and under several and multiple possible wordings of key terms. Sources were then analyzed regarding the context of theory, methodology, data, analytic techniques, sampling and references before accepted for consideration in this dissertation. We searched for the "state of the art," the extent of knowledge, and the main issues regarding the dissertation topic.

Multiple qualified sources (information system inputs of relevant work in this area) serve as the foundation for the dissertation. These sources provided the data (raw facts and figures), which was manipulated and recorded as information (processed raw data and figures) to support the theoretical propositions and rival explanations.

The systemic mechanism of the industry is a philosophical topic that requires a philosophical analysis of the meaning of building construction systemic mechanism with respect to its capacity for change, rather than of metrics. For this reason, we use philosophical tools in analyzing the phenomenon of inventions, technology and science applicable to a building. We discussed this query extensively under the umbrella of epistemological and ontological methods. Scholars and experts were consulted on the writing legacy of prominent philosophers on this subject.

On this foundation, we proceed with the most promising characteristics of the physical form as unit of analysis keeping in mind the pressing subjects of the challenges, and our Systems of Interest. For example: Population has to do with numbers that in a limited space/volume (world) translates to density. We determined that verticality of shapes, which are conducive to higher densities, is a better attribute of the physical world to study (i.e. than clear spans), since we are limited by time and resources. High-rise buildings (Goldberger 1981; Peters 1987; Sabbagh 1990; Fitchen 1986; Eisele and Kloft 2003), illustrate the complexity of large-scale technological developments (Iansiti 1995), that is, a number of necessary inventions and technologies that emerged independently but coalesced in the high-rise building.

Other building types, such as hotels, are also good repositories of building innovation and technology (Pries and Janssen 1995; Slaughter 1998; Tatum 1996), some even achieving high-rise status. In the 1800's there was a shift from shelter from cold, rain and wind to 'ambience,' according to Sebestyén (1998), captured by the hotel industry's history. In a way, this move from basic elements into 'ambience' is parallel to a move from basic needs to wants. Luxury hotels have traditionally displayed the latest technologies, showcased by the following abbreviated selective chronology (Berger, 1995):

1829 The Tremont House, Boston (called the first modern hotel): Seth-Fuller annuciators, gas lighting in public spaces, indoor plumbing (piped cold water to kitchen and laundry, bathing room and public water closets, steam heat, lift (bell boys) and room lock and key

1833 Holt Hotel, NYC: Steam engine, pumped water, hoisting of baggage and clients.

1836 Astor House, NYC: Gas plant with gas lighting in all guestrooms and public spaces, hot and cold running water; water closet on every floor, steam engine supplying power to the kitchen, commercial laundry and the plumbing system.

1859 New York Fifth Avenue, NYC: Vertical screw railway passenger elevator serving five floors is steam driven and designed-built by Otis Tufts

1875 The Palace, SF: Noiseless water closets, electrical signalling system, roof top fire extinguishing water tank, earthquake proof construction, seven stories tall

1890 Plaza Hotel, NYC: Steam heat, gas and baths with hot and cold water

1904 St. Regis, NYC: Ventilation system, central vacuum system, electric motors, automatic thermostat in guest-rooms

1913 Statler Cleveland Hotel, OH, Statler Detroit, MI, Statler St. Lewis MS: Private baths, non slamming guestroom doors, telegraph, Herzog teleseme and teleautograph

1993 Four Seasons Hotel, NYC: Computer terminals, fax machines, color TV, self-filling fast tubs, bedside blind controls…

The high-rise building remains a more compelling building type (Eisele and Kloft 2003) that incorporates, by its nature, the latest technologies (except perhaps hospitals) and thus the model selected for analyzing the systemic nature of the industry as well as its mechanisms and capacity to change.

As previously stated, mechanisms for change, and change itself, is difficult to analyze (Beer and Nohria 2000) because they are embedded in the evolution process of the industry and this evolution process does not readily reveal the forces that have created it. Building's increased verticality (increases in the height attribute) is a global, historical and international challenge on building methods, materials, theories etc, with embedded historical change mechanisms.

Building's increases in verticality throughout history (high-rise buildings) plotted against time and historical milestones and notated using Masterformat Level 4 or similarly CSI (Construction Specification Institute) divisions that capture the topics of this breeding ground. Masterformat and CSI provide the ontological framework for analysis. A time/building-height graph (see Chapter 4) is baseline for an inductive analysis of the mechanisms for change in the industry breeding ground.

Structure, (gravity, earthquake, wind loads theories and practices), electricity (pumps, lighting, communications), vertical transportation (elevators) and skin (materials and systems) are obvious contributors and surrogates of innovative changes in the industry, thus pointers of the embedded mechanisms for change. For the pilot study, in order to analyze the mechanisms for change at a greater level of detail, we have selected mechanical systems, and specifically the advent of air conditioning, part of the mechanical systems dealing with air, water and waste disposal.

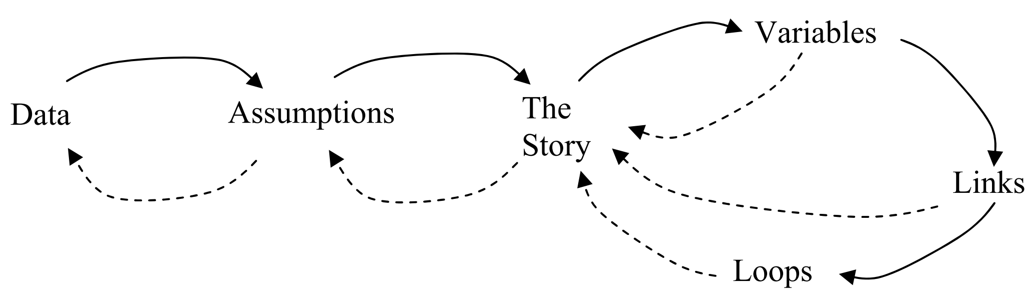

Fig. 1.3 Method for Drawing Causal Loop Diagram (Shibley 2001)

Causal Loop Analysis (CLA) from Systems Dynamic Modelling (SDM) (Anderson and Johnson 1997; Spector et al. 2001) techniques were used in the pilot study to derive useful information that is interpretative of the data content of the graphs, see *Figure 1.3*. Furthermore, Soft System Modelling of any product is shown in *Figure 1.4*. Causal Loop Analysis is an iterative method for driving out of a story the variables, links and loops and the substantive assumptions and data that can be used to back the story line.

Beginning with the story or event (CLA is based on the understanding the world as a series of events) one proceeds through a process of identifying the variables, establishing links between variables and creating loops based on the links.

The purpose of CLA is to find if there is a systemic structure driving the finding of trends, directions, magnitudes (increasing or decreasing) and any other metrics that can substantiate the findings. A variable should be measurable (that is a trend chart of the variable

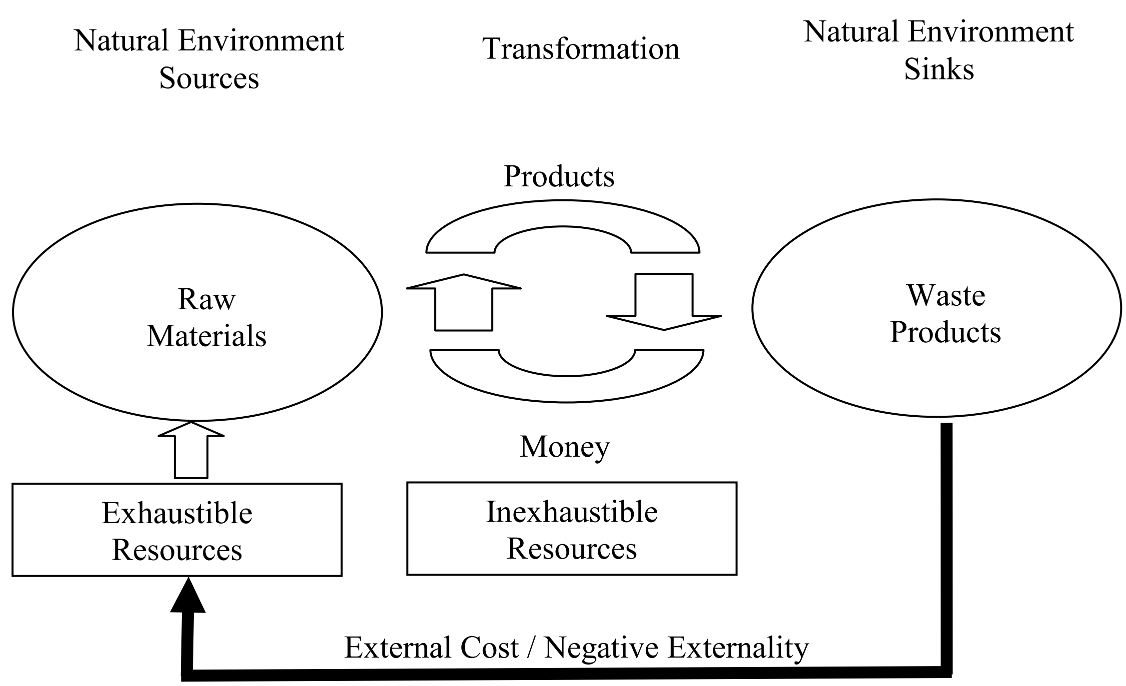

Fig. 1.4 Soft Systems Modeling Example

desired) and describe the things that actually change. Variables are those things in the story that change, that increase or decrease over time.

The CLA methodology is based in the discovery of increasing levels of complexity from events (the world as a series of describable events); patterns (leverage begins with pattern recognition, that is: this has happened before – which is a basic insight not always readily recognizable and obvious); study of the systemic structure (documentation of the systemic dynamics that maintain the CLA). Once a pattern has been identified and described, it is possible to document the systemic dynamics that maintain it. The level of systemic structures marks the boundary between what can be easily observed in the objective world (events and patterns) and what must be assessed, often laboriously, from the data (using mental models and visions).

Mental Models are assumptions that may be un-conveyable theories on what constitutes quality, good service or an acceptable return on the investment. These 'theories in use" may also treat interpersonal dynamics, or events dynamics. All of these levels (Events, Patterns, Systemic Structures and Mental Models) are informed by Vision. The key question at this level is "What do we want to create?" or taken retrospectively "What do we seem to be creating?" These aspirations, stated or un-stated, exert a powerful influence on the events, patterns, systemic structures and mental models in any given situation.

Causal Loop Analysis revealed in the pilot study that the forces behind these mechanisms for change are in the case of air conditioning: People (needs and wants), Entrepreneurship (initially seeking an ice making machine), Theoretical Developments (thermodynamics and psychometric formulas) and Process Improvement (above, ceiling distribution in lieu of below, floor distribution as in heating). These findings lead us to believe that the mechanisms for change embedded in the industry are mined and analyzed at a relevant and insightful level of detail (i.e. the Industrial Revolutions as a source of change; the high-rise building as a building type embodying change (Eisele and Kloft 2003); air condition and elevator as sub-systems embodying technological change). The metrics between the levels of creativity, innovation and progressive development of theories and practices are difficult to analyze directly. A surrogate method for analysis is proposed through a vicarious scale termed the "taxonomy of change" that is explained later on. Each loop complex in a CLA may have its own metrics. For example, in air conditioning the level of complexity of the basic machine and controls have increased over time and is a surrogate for incremental change. The jump from a mountain carved and transported ice block used by the Romans to a rudimentary ice-making machine conceived originally as a way to 'cool buildings' is a step change.

Future work is proposed to use this methodology in analyzing the other four of Sebestyén's identified components (structure, electricity, vertical transportation and skin), with the understanding that this list may not be complete and conclusive, but will serve the purpose of delimiting the scope of this work due to time and resource constraints. The expectation is that this type of analysis will reveal definite patterns and trends of the mechanisms for change within the systematic nature of the industry. However, this sought-of pattern or frame of reference should fit within a larger schema. The General Schema, discussed later on, is tentatively proposed as a frame of reference that has the capacity of tying in the natural and artificial environment, specifically the built environment.

1.2.2.1 Philosophical Approach

Building construction appears to be an industry of industries, were its capacity for change is observed. Both the challenges and the capacity for change of building construction are philosophical issues, concerning what they mean rather than what they define, which requires a historical exploration[43]. Building construction as "technology" can be interpreted as a special myth (Munford, 1967), in relation to human self-definition (Ortega y Gasset, 1939), as posing ontological questions (Heidegger, 1954, 1962), or as a risk-fraught attempt at total control (Ellul, 1954). In agreement with Mitcham (1994) building construction as a technological act relates to a non-technological dimension of reality.

The word 'hermeneutics' (Mugerauer 1995) in its original development was an attempt to reach out for sympathetic understanding via the humanities discipline rather than a logical explanation via scientific and technological ones. Kuhn (2000) argues that the natural sciences of any period are grounded in a set of concepts that the current generation of practitioners inherit from their immediate predecessors. That set of concepts is a historical product, embedded in the culture to which current practitioners are initiated, by training. These concepts are accessible to non-members only through hermeneutic techniques (Mumford 1934, 1967, 1970; Mugerauer 1995) by which the historian comes to understand other modes of thought. Kuhn (2000) has spoken of the historical culture as the hermeneutic basis for the science of a particular period, and it bears considerable resemblance to one of the senses of what he once called paradigm… though he seldom used the word 'paradigm' later in his life having totally lost control of it.

The essence of technology, per Dessauer (1927, 1956) is encountered not in manufacturing or in the product but in the act of technological creation. The unique act of inventing is: that which did not previously exist and actually functions or works. Inventions are new creations not previously found and actually work or function. We shall consider inventions (defined as first time technologies), innovations, improvements and changes (defined as other

[43] Kapp (1845) History is the differential record of human attempts to meet the challenges of various environments

than first time technologies), in the identified 'change taxonomy', insofar they have a possibility of drastically or exponentially increasing or magnifying the original invention function or capacity for work.

According to Heidegger (1954), "modern technology (creation, invention) not only covers over or obscures the 'thinghood' in things; it also covers over or obscures the 'Being of beings' and ultimately itself. Technology can not be understood in terms of technology." From this we gather two valuable observations. First, building construction is this amorphous background, where the creative process dwells; and embeds and obscures the generative process in the created object. Second, if indeed technology cannot be understood in terms of technology, we must enlist the hermeneutics (Mugerauer 1995) of the humanities in order to bridge the gap that science and technology leave in understanding itself.

The generated output, the built environment, reflects the industry, in and by itself it does not readily reveal the forces that have created it. The generated objects mostly reflect the breeding ground of ideas, theories, technologies and values, in other words the heuristics of the state of the art that existed within this 'fragmented' industry. (See Appendix L for some observations on the concept construction 'industry').

Qualitative and quantitative data concerned with building construction and its embedded 'technology' is collected from qualified historical archives. The analysis, instead of only being based just on hard systems (OR) thinking[44], as previously mentioned, has taken both a hard and a Soft System[45], heuristic approach. We have supported our choice of this method of analysis by

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(regarding technology – to overcome dependence on raw nature).

[44] Midgley and Reynolds (2004) describes systemic thinking (Churchman 1971, 1979 and Flood and Jackson, 1991) involving: (i) systemic approach , (ii) systemic intervention, (iii) systemic boundary critique and (iv) critical systemic thinking.

[45] Systems is used in the sense of System of Interest (SoI) a map of real world territory with some human relevance

posing the right question[46], rather than seeking some absolute truth through advancing supposedly right answers. Different techniques are contemplated for the study depending on the area for investigation.

1.2.2.2 A Purely Theoretical Schema

The purpose of this section is to establish a schematic link between the natural and the artificial environment though an existing or adapted schema. Furthermore, the identification of this schema brings with it an understanding of the nesting and the relationships of systems, at a conceptual construct that will be used throughout this dissertation as an aid to understanding how the parts fit with other parts, the concept of holes where things are created, sink into oblivion, or just happen, and the concept of boundaries. Our position is that the knowledge and understanding of the relationships in the schema are transferable from the natural environment to the artificial environment in general terms.

In a dissertation such as this one, a schema provides the initial framework a paper napkin conceptual sketch that captures the intent, highly heuristic/theoretical as it may be and rightly so, through which the nesting of the complex web of relations can be initially discerned. After identifying the salient issues through literature search, we looked at several framework systems from a highly theoretical vantage point to gain insight on a schema that would frame the issues within themselves and with the major themes of the natural and artificial environments.

The criterion for selecting a schema is as follows:

1. Does it show how the built environment and the natural environment relate, what can we say or speculate about their methods of interactions, and what events are highlighted?

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[46] Churchman 1971: The boundaries of the systems are initially defined in terms of purpose and extended in 'a sweep in process' whereby boundaries of a purposeful system are extended to incorporate different meanings, and secondly, a 'process of unfolding' a critical counterpart where the boundaries are more critically examined with respect to different meanings.

2. Is it able to compare the corresponding categories, i.e. systems with systems, form with form, etc. among differing environments (natural and artificial)?
3. Can transferable knowledge from a general schema theory evolve as an ontological template for a proper body of theories?
4. Does the schema, even in its heuristic/theoretical structural form, captures significant features of scientific theory and practice notably absent from the earlier formalisms?
5. Does the schema lend itself to exemplary applications both from the natural and artificial world constructs?
6. Can progress occur either by discovering new applications which can be identified extensionally as members of the set of intended applications, or else by constructing a new theory-core-net (a new set of expansions of the core) or a new Schema?

The 'General Schemas' is a theoretical proposition and is the subject of Palmer's (2003) second Ph. D. dissertation presentation and defense. It is presented in this study as an unproven theoretical model. This adaptation of the 'General Schemas Theory' provides an ontological view of possible levels of interaction between the ecological and artificial domains, the natural and built environments (artificial) and the areas of population, resource, and waste with building construction.

In particular this General Schema (see *Fig. 1.5,* Palmer's contribution in dashed-line box) is useful in showcasing the upper and lower limit of our discussion. This study in particular

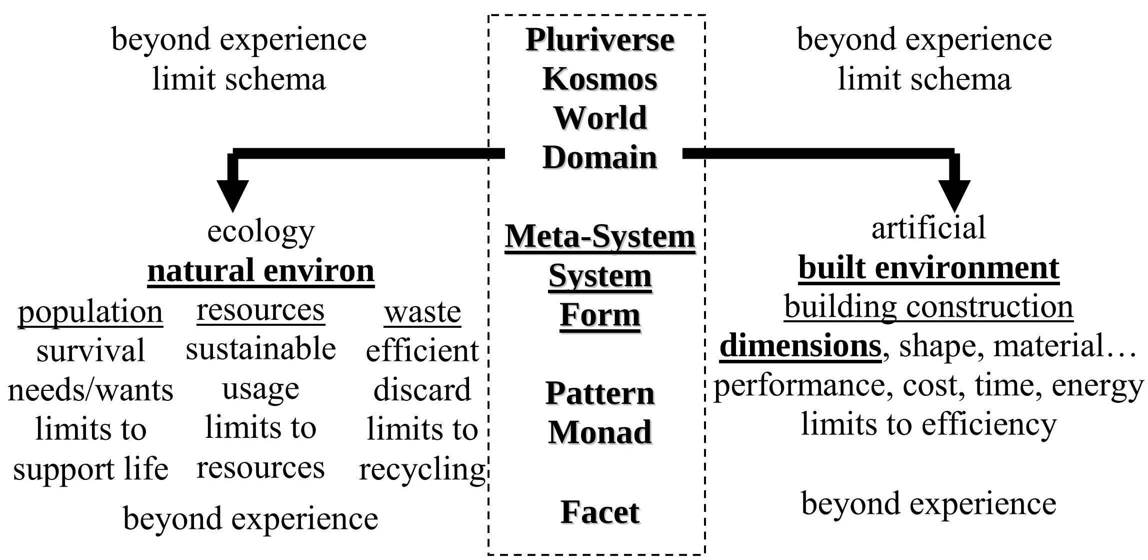

Fig. 1.5 General Schemas Theory" Adapted from Palmer, 2001, 2004, Ontological Hierarchy in "General Schemas Theory" See http://holonomic.net , http://archonic.net

looks at how man-made systems-in-place (artificial) impact the meta-system called Ecology (nature) that can change from a "normal" mode to a "dynamic" mode resulting in paradoxes, contradictions, anomalies, with catastrophic consequences and possibly even madness.

According to Palmer (2004, 2003, 2001a and b, 2000), meta-systems have four complementary aspects: Origin, arena, source, and boundary[47]. Of special import is the aspect of arena where systems interact. Arena provides the resources and constraints that include the testing regime that reject systems from niches within the meta-system that do not conform to the interfaces of the meta-system.

We have, according to Palmer 2003, no general theory of meta-systems other than that which we are given by the discipline of ecology! In our case, what we are talking about is the boundary of the meta-system of nature and a built environment meta-system that was not designed in a way sensitive to ecology. The nature meta-system and the artificial built environment[48] meta-system are nested within a higher order meta-system, which is the world, the entire environment planet wide.

Similarly, Bataille (1991 - 1993) calls this higher nesting level the "General Economy" and all the systems we identity within this global meta-system are called "restricted economies". Systems can be nested and so can meta-systems like Russian nesting dolls[49]. But these nesting interleave so that there is an alternation of system, meta-system, system, meta-system when they

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[47] Boundary in this context is defined by Palmer as a transition to where other Meta–systems than the one in question exist.

[48] In fact, we know most about meta-systems from the artificial ones we create in such a way that we can track closely to their projections while nature and its meta-systems go beyond the bounds of our projections and that is why there is a disconnect between projected meta-systems onto nature and nature itself which we discover through anomalies that break through our projections, such as the case of this study.

[49] Indefinite nesting is the fact that we have complementarities of complementarities of complementarities… within existence. That is what existence is. It is indefinite because we do not know how far down it goes in terms of finitude of existing things, while ideally it is infinite. This is the groundless ground from the point of view of Being, but the Bedrock of Existence. So if we look for a ground for anything we do not find it that is why things are intrinsically empty or void depending if the starting place is consciousness or nature, logos or physus.

are taken together. An important question is posed by our study: What is nature's testing regime for rejecting systems and other meta-systems that do not conform to the interfaces requirements of nature's meta-system?

Meta-systems are essentially different ontological schemas[50], or templates of understanding, and are ways for looking at the world (see *Fig. 1.5,* also see Appendix E). The meta-system view does not look at the system which is seen as a social gestalt, that is a whole greater than the sum of its parts. Rather, the meta-system view sees wholes less than the sum of their parts, i.e. wholes with holes in them, likes that of sponges, except that the holes are niches within which systems reside in their environment. Meta-systems are the field, the environment or ecosystem[51] containing systems, which interact often in unexpected ways.

The point is that meta-systems have structure just like systems have structure, but the structure is different in each case, and our culture has a bias against meta-systems (or a preference for systems) so we find it difficult to see meta-systems. Rather we see systems everywhere without seeing the meta-systems that these systems are embedded within. We really need to see both and alternate in our analysis between these two very different views of things. In summary, meta-systems, the complimentary inverse dual of systems is full of holes and the whole is less than the sum of the systems nested in its field. Are the systems'[52] schemas applicable or transferable as methodology, paradigm, episteme and/or ontology to the study of ecological challenges and building construction capacity for change?

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[50] Currently we have no theory of the schemas that appear in the Built Environment. There is a systems theory but not meta-systems theory, a blind spot in our culture.

[51] Ecosystem is used in this study as an interacting system composed of biological, non-living physical environment as well as the artificial (man-made) physical environment.

[52] The relationship of systems to meta-systems duality is the topic of the discipline of Holonomics from the Holon of Koestler (1967), which is both part and whole at the same time. "The system within the meta-systems is a whole greater than the sum of its parts, within a whole is less than the sum of its parts."

Philosophical categories and schemas are important for understanding the relation between our theories of phenomena and the phenomena themselves. The phenomenon goes beyond our schemas, but the schemas are the basis for our understanding the phenomena by providing a heuristic, inner coherence through a specific projected organizational template. The schemas bridge the various theories by providing an underlying unity of understanding, an inner coherence, which in turn is based on the fundamental concepts (ontology) provided by the our social construction of the mind in terms of embodiment.

Ontology is defined as: an understanding of the various "kinds" and "aspects" of being. The "kinds" of being are: Pure[53], Process[54], Hyper[55] Wild[56] and Ultra[57]. The "aspects" of being are: truth (x is y); reality (x is); identity (x is x); presence (this is x). The relations between "aspects" are properties such as:

- Formal systems normally only consider relations to truth, identity and presence, that is consistency, completeness, well formedness (clarity)
- Taking into account reality adds coherence, verification and validity

A meta-system has its own essential structure that is fundamentally different from the ontology, reason and logic that we normally appeal to. We can not assume that meta-systems are just an extension of systems and that the rules that we have in systems are transferable such as it is just more of the same. We must produce something like model theory[58] but inverted and at a higher level of generality in order to understand the different logic. What we need instead is a kind of theory that combines systems theory, which is rooted in universal algebra, and a meta-

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[53] Pure: Called Present-at-hand by Heidegger (1962)
[54] Process: Called Ready-to-hand by Heidegger (1962)
[55] Hyper: Called the Hyper-dialectic of Process Being of Heidegger (1962) and the Nothingness of Sartre by Merleau-Ponty, (1968)
[56] Called Wild Being by Merleau-Ponty (1968)
[57] See "Metaphysics of Emergence" by Palmer at http://archonic.net

system theory that is a kind of non-classical logic[59] that comprehends the structure of paradox and absurdity (Hellerstein 1997).

Why this forage into meta-systems? We contend that by logic and common sense we can ascertain that building construction is not a homogeneous industry; some even say it is fragmented (Gann, 1996; Pike 2002; Woudhuysen and Abley 2004). This points out to the possibility that the background we call building construction is formed of many industries of many systems and many subsystems all interacting independently and autonomously at multiple levels. A system of systems is a meta-system. A meta-system, as observed, has logic, paradox and absurdities. A meta-system is less than its parts therefore inefficient by nature. A meta-system has many holes that are breeding ground fertile for inventions, innovations, adaptations, and new creations and a quick sink for those that do not make it.

The question then is: Has Building construction or construction in general the structural and systemic characteristics that fit the definition of a meta-system?

1.2.3 Method of Analysis of the Capacity for Change

Before we can talk about a method of analysis we must come to terms on what is meant by ‘capacity for change’. To probe this understanding we searched Popper (1972) philosophical insights on the nature of world constructs to determine if ‘capacity’ is an attribute of the physical, subjective or mental world[60]. This subject will be treated in more detail later, thus for now we will be using the following working understanding of where the ‘capacity for change’

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[58] Model theory is the combination of universal algebra and classical first order logic. Algebras relate to reason through countability, a fundamental perceptual and motor action that gives us the basic substructures for the differentiation of our concepts (cf. Lakoff & Johnson 1999).

[59] Non-classical deviant logic: A logic that comprehends paradoxes, supra-rationality, and contradictions, that is a Para-consistent or Para-complete from the point of view of logic.

[60] According to Hawking (1998) there is a paradox in the subjective observations of the universe. We are rational beings who are free to observe the universe as we want and to draw logical conclusions from what we see. Yet the theories themselves determine the outcome of our search for them.

resides in order to talk about a method of analysis: the ‘capacity for change’ is a theory, defined with a philosophical language constructed by a subjective mind, see *Fig. 1.6*.

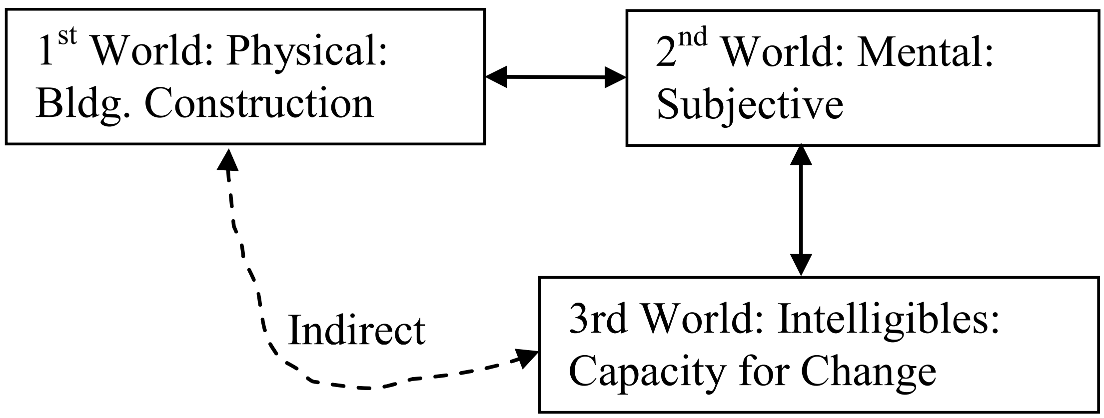
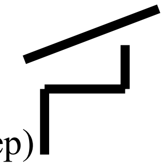


Fig. 1.6 Understanding of the concepts of Building Construction and Capacity for Change (based on Popper)

The ‘capacity for change’ reality transcends the creative mind. In other words, just like a physical reality exists separate from the creative mind, so does a ‘capacity for change’ exists separate from the creative mind. Particularly, in the context of this study topic, the ‘capacity for change’ has an indirect link to the reality of building construction, which has a potential for physical change while in the process of conception and creation. Afterwards that capacity becomes transfixed and embedded in the physical building, the current source of our dilemma. The physical change manifests as an ‘activity’ of nature or another agent, such as human activity. This study focuses both on human activity that actualises the capacity for change within the systemic nature of the industry’s mechanisms for change as well as a ‘capacity for change’ forced by nature’s cataclysmic events.

Incremental – small (gradual)

Systemic – multiple, linked, rapid (step)



Radical – (new) breakthrough in science or technology

Fig. 1.7 Change Taxonomy

Current trends and initiatives are subjective human realizations from a ‘capacity for change’ that in a Kantian sense exists in the real of undiscovered possibilities, prior to their discovery. This capacity for change is indirectly tied to the potential of the physical reality (identified as a “problem” or “puzzle” to be solved – Kuhn 1962, 1976 & 2000), or the activity called building construction (theories and error elimination processes) and the final physical product called building. Using Popper’s (1972) philosophical method of analysis (Conjecture and Refutations)[61], coupled with the created change taxonomy[62] (see *Fig. 1.7)*, when applied to current trends and initiatives, points to building construction’s current expected/hoped capacity for change.

The dissertation uses ‘change taxonomy’ as concept and not as a tool for arriving at a quantifiable metric. As a conceptual construct, the dissertation addresses the issue of the forces that create and tame exponentialoid growth. Although those forces have incremental and systemic components, historically, the advent of radical (new) breakthrough in science has been

[61] Popper’s method of Conjecture and Refutations is similar in nature to Checkland’s (1981) problem description whereas S_1 is the desired state and S_0 is the present state with alternative ways of getting from S_0 to S_1. “Problem solving” according to this view, consists of defining S_1 and S_0 and selecting the best means of reducing the difference between them. However this is ‘hard system thinking’ and does not fit the intent of this study since P_1 is a step on the way of ultimate potential but not the end.

what propels the 'next' Industrial Revolution. As a matter of fact, history analysis alludes that incremental and systemic change inevitably have a life cycle of growth, apex and decline, a sober lesson to all of our efforts at increasing efficiency and effectiveness to our current systems. Philosophically speaking a technology has an integral seed of obsolescence: Technology begets technology resembling a life cycle.

If we are facing the forces created by Industrial Revolutions, 'the elements that influence exponentialoid growth,' the solutions to the problems of resource consumption and emissions generations do not appear to be along the lines of incremental or systemic change, but on the next wave of radical new breakthrough in science or technology.

The counter-argument may be that incremental and systemic efficiencies may be contributors to the solution, even substantial contributors to the solution, as if automobiles achieving more miles per gallon in an attempt to save a beloved and dependent technology. However, the need for taming an exponentialoid is radical technologies that use no fossil fuel and relegate remaining stock to those irreplaceable processes.

A worldview, paradigm, mindset in Popper's scheme (*Fig. 1.6*) belongs to the 2nd World: Mental and Subjective that informs how the 1st World: Physical, is perceived through 3rd World: Intelligibles such as Forrester's model. Therefore, the 2nd World construct, the mental and subjective worldview, paradigm, mindset that frames reality is our primary focus. Hawking (1998) describes 2nd World constructs by the anthropic principle (weak and strong) which can be paraphrased as "we see the universe the way it is because we exist."

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[62] This change taxonomy interprets gradual such as the progression from charcoal, coke, coal, and oil (chemical); Step such as nuclear energy (atomic); and New such as nano technology (micro technologies)

1.2.3.1 Partnering 'capacity for change' pilot study

Take for example the issue of partnering[63] (Bennett and Jayes 1998b; Godfrey 1996; Rackman et al. 1996) as presented in the pilot study and analyzed using Popper's method of Conjecture and Refutations see *Fig. 1.8.* Partnering addresses organizational issues (Baden 1995), and the analysis indicates that the changes proposed by partnering can be categorized under the proposed taxonomy for change, as gradual for making sense of the organizational / process world in order to better 'manage and control'. The process of the organization is defined in practice by its participants, rather than by written documents – theories in use rather than espoused theories (Argyris and Schön 1974, 1996).

Partnering acknowledges that building construction organizations for a project are in a negotiated enterprise (Strauss and Schatzman, 1963) whose participants are continuously negotiating and renegotiating their roles within it. Organizations and individuals come together to form a 'consulting practice' which centers on the role of negotiation in effective problem solving. The consulting practice comes together for a project that exhibits the characteristics (Nam and Tatum 1988) of one of a kind (Riis et al. 1992), on a particular site construction, by differing teams (Koskela, 2000). Furthermore, partnering acknowledges that the consulting practice is composed of individuals, teams and organizations that act autonomous, thus the potential for positive synergy as well as discontinuities and constraints. The partnering

[63] Partnering is characterized by a "model based facilitated group device" for a problem situation with the full 'swamp" characteristics. Partnering sessions are iterative with the initial trial version of the model being successively improved by the group in future sessions. All stakeholders have to be present to form non-binding covenant whose outcome is not unacceptable to the constituency, although this may be conditional on members checking back with their bases since the area of interests are both possible different perceptions and differing interests of the project and processes. No member 'whole problem' is dealt with so each stakeholder can realistically hope to make progress only incrementally with his or her key concerns. (Adapted from Rosenhead and Mingers, 2001).

consultant is the instrument for facilitating this negotiation, and for managing consensus and commitment (Bennett and Jayes 1998b).

This method of analysis helps to identify the origin of the trend or initiative, its nature (what generated it), the change, and what can we say about the trend capacity to meet current challenges (the residual problem). See Appendix J for a more extensive treatment of the pilot study using this methodology.

$$Pu_1 \longrightarrow TT\,u \longrightarrow EE\,u \longrightarrow Pu_2$$

i.e. Partnering (organization related):
Pu_1 = Lack of teamwork, litigiousness
TTu = Agree on Project Success Criteria
EEu = Problem resolution scale
Pu_2 = Non-Binding Charter

Popper's Analytical Process of Understanding: *Pu_1 = Problem (original) of understanding; TTu = Tentative Theory of understanding; EEu = Error Elimination of understanding; Pu_2 = Problem (emerging) of understanding*

Fig. 1.8. Analysis of Partnering using Poppers' method of Conjecture and Refutations.

1.3 DISSERTATION OBJECTIVES

The main objective of this pre-paradigmatic dissertation is to create a worldview that frames building construction sustainability and building construction's capacity for change (in response to the sustainability issue).

The sub-objective regarding sustainability is: first, the identification of the links between different forces affecting sustainability; second, identification of characteristics of the elements that influence the forces affecting sustainability; third, to gain a better understanding of the relationship between the growth curve characteristics and the elements that influence the forces affecting sustainability.

The sub-objectives regarding building construction response capacity to change are: first to better understand the nature of complex nature of building construction; second determine where building construction's capacity for change resides; third, identify the elements that influence the forces affecting building construction's capacity for change; fourth, how (in a purely theoretical scenario) building construction capacity for change could be marshaled to generate the forces capable of affecting the growth curve.

The expected deliverables in this dissertation are: (1) A better description of the challenges to the building construction industry in this Century (the exponentialoids and how they relate to building construction); (2) A theoretical framework/model of how these challenges and the industry interact (identification of the elements that historically have influenced change); (3) A study of the industry's systemic nature (the complexity of the industry); (4) An analogue graph or model of the interaction between the historical mechanisms for change and the exponentialoid).

1.4 CONCLUSIONS

This chapter addressed the motivations for this study as the need for a better understanding of the nature and magnitude of the challenges that confront the building construction industry. The scope was deliberately narrowed from ‘general construction’ to ‘building’ because of time constraints and subject-matter experience. We have identified the problem, and raised provocative questions like: who says that there is a problem and the ‘so what’ of the problem.

We have identified the types of methodologies and the reasons for choosing them due to the nature of the topics of interest with the understanding that more work is needed on the systemic nature of the building construction industry that is supported by work on the complexity of the industry. We have identified the stakeholders that have an interest in the subject of this research and alluded to sustainability as the key issue for resolving the problem.

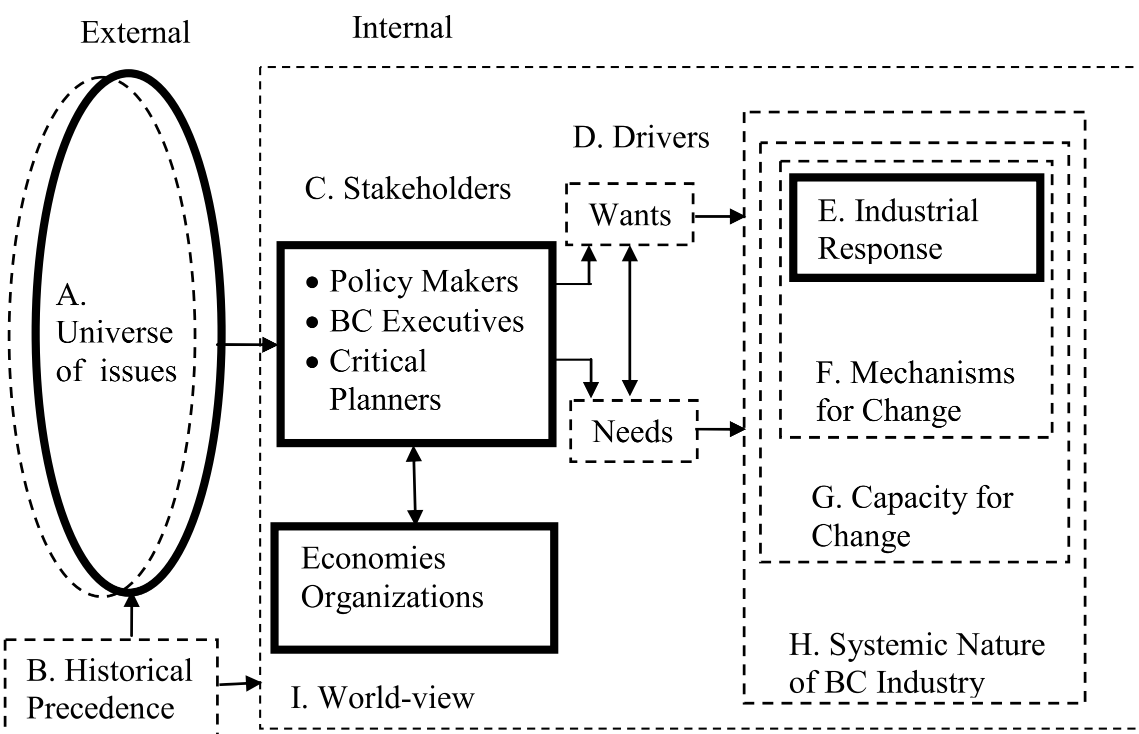

Fig. 1.9 Schema of macro-issues flow. Dashed = embeded

We have also alluded to a lack of worldview, schema and paradigm that may be behind the current predicament of an industry. We propose a specific schema (see *Fig. 1.9 Schema Underlying this Dissertation*) as basis for this work. From the universe of issues (A) with historical precedent (B) we have selected the problems that are of interest to the stakeholders (C) and will clarify the drivers (D) that fuel the problems and elicit an industrial response (E) of an industry (H) with an embedded mechanism and capacity for change (F & G.)

In the end, this dissertation is a contribution to the philosophical field of knowledge by advocating an innovative method for analysis and theory building of the challenges and the nature of building construction industry with respect to its capacity for change.

We chose the focus of this dissertation, the identification and analysis of the underlying mechanisms and forces, the connection between exponentialoids, sustainability, and building construction because of the situation permits no delay, a pre-paradigmatic work is needed since there is no theory, and the reasons for selecting it, in the words of Descartes, "are excellent."

CHAPTER 2

CHALLENGES TO THE INDUSTRY

I meant no harm.
I most truly did not.
But I had to grow bigger.
So bigger I got.
Dr. Seuss

In this chapter we are going to address the issue of industry challenges by building on the basic drivers of population numbers, demographics (change from developing to developed status by large segments of the population), a case study of China (example of the number and demographic change), the underlying reasons for those changes (the universal drive from needs to wants), and how population numbers have increased in a historical time line. The reason for this sweeping, universal, overarching approach is that we lack a worldview, a schema of the problems and therefore a clear understanding of the nature and even more the magnitude of the problem.

We are going to focus on the question of exponential growth, first in population, and secondly on population dynamics (demographics). These exponential growths telescope into all other areas, specifically into building construction's rate of resource consumption and emissions generation. What we found during this focus is that nature had its own way of defining 'sustainability' which human benevolent intervention (towards the human race specifically) negated unleashing an exponentialoid growth. The possible reason for uncontrollable growth is because there is no single cause for this growth. The implication of this growth is that it occurred in a very specific historical period, what we call the Industrial Revolution[64]. Therefore

[64] *Other events in what is called the pre-industrial revolution have affected construction such as the period known as the Middle Ages (from 400 to ca. 1350) and the Reformation (ca. 1350 – 1750) with ecclesiastical and*

the next step in the argument we are trying to build is to tie population growth with the events of the Industrial Revolution to see if we can determine the elements that influenced the exponentialoid. The hope of this approach is that finding the elements that affected nature's sustainability and unleashed the exponentialoids, we can then transfer that logic and see if we can identify the elements of influence of change in building construction. However before we take that step we need to better understand the concept of complexity and the systemic nature of the industry.

2.1 INTRODUCTION

The building construction industry is at the crossroads of traditional and innovative ways of constructing and thinking about construction (Syben 1993). Moving away from its tradition-bound character, construction is increasingly open to progress and its segmented structure is evolving towards integration, which 'appears' to be favorable for advancement. Decisions and changes in the industry are motivated by challenges. Some challenges are internal from the industry, such as organization, management, and information while other challenges are external such as social, economic, political, environmental and demographic. These challenges are of varying magnitude and the elicited changes in the industry may affect anywhere from the way a task is completed to the collective working-assumptions that guide social life.

According to Kuhn (1976), there are a few periods in history that deserve the label of "transforming eras," during which circumstances changed sufficiently in response to challenges to warrant a major shift of assumptions in what he calls a paradigm shift. This transforming era paradigm shift occurs when people depend on working assumptions that become so inappropriate that they break down to be replaced by a more appropriate set. Likewise, building construction

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monumental public buildings. However these period have not transformed Western civilization in the broader sense history is affected by internal and external forces that are characterized by long periods of stability in a paradigm, punctuated by relatively short periods of high instability (pre-paradigm shift or crisis). This exemplifies history as a staircase rather than a ramp (Kanter, 1983). The current Building Construction industry crossroads, when considering the magnitude of the challenges, may be at a historical pre-paradigm threshold, a time that to surmount the crisis an exponential step will need to be taken.

Literature search indicates that most of the current changes in the industry are focused on internal aspects such as: project management (Miozzo and Ivory 2000; Drucker 1963, 1970; Tushman and Anderson 1996; Morris 1994' PMI 2000, 2002), productivity (Oglesby et al. 1989; Parker and Oglesby 1972; Ballard and Howell 1998a, 1998b, 2003a, 2003b, 2003c, 2004; Ballard 1999, 2000, 2005; Berger 2005), processes (Allen 1985; Atkin 1999, Lathan 1994; Egan 1998, 2002; Fairclough 2002; Saxon 2002), industrialization (Sebestyén, 1998), fabrication mechanization (Slaughter, 2000), performance (Foliente 2000) and productivity (Kanter, 1983; Tang and Ogunlana, 2003; Chan and Kumaraswamy, 1996), knowledge management (Egbu, 2004), and information technologies (FIATECH, 2004). This is no surprise since technology is focused on finding efficiencies. Ellul (1954) states that "technology has taken over the totality of human activities… it is progressively unified and the same everywhere, expanding according to its own dynamics… in search for the one best way to achieve results. It resists incorporation into or subordination to non-technical attitudes and way of thinking. Technology is the totality of methods rationally arrived at (and aiming at) absolute efficiency (for a given stage of development) in every field of human activity.

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that the Industrial Revolutions have and occurred at a time of rapid population growth

Some challenges are focused on identifying a theoretical basis for innovation (Pries and Janssen 1995; Slaughter 1998; Tatum 1996) and a theory for building construction (Koskela, 2000). Innovation theories and theory creation initiatives are based on benchmarking other industries, as captured in CIB's *Revaluing Construction 2005* International Conference proceedings. In contrast Koskela and Vrijhoef (2001) propose that the theories of project management (Miozzo and Ivory 2000; PMI 2002, 2002), imported mostly from the manufacturing and industrial production industries, are obsolete. Koskela and Howell (2002) furthermore observe that current project management theories and praxis are a hindrance to innovation.

The call for 'radical' change and innovation are current topics of intensive attention in the industry (Koskela, 2003; Seaden 2000a; Seaden et al., 2000b; Tatum, 1996; Widén, 2002, Egbu 2004). However, the challenges contemplated in this study are based on a deeper topic than "how to become more like manufacturing." Some of these more challenging topics are population growth /demographics, environmental/climate change degradation (Foltz, 1995), sustainability – use of natural resources (Stefanovic, 1991).

The topic of sustainability in the construction industry has been addressed from an economic, economic accounting (macro-environmental-economics-by Pearce 2003, 2006; nCRISP 2004); auditing sustainability in construction, Turner (2006); Issues of human capital in construction sustainability, (Briscoe 2004); and A European perspective on the Pearce Report by Kohler (2002, 2005, 2006); Carassus (2004) meso-economy and sectors. These and other works will be treated in more detail later on. However, these approaches do not address the challenges as framed in this dissertation, the root of the problem and our next topic.

2.2 THE CHALLENGE OF POPULATION GROWTH

What is the problem envisioned in this study? In other words: What is the nature and magnitude of the challenges? The first challenge that we are considering is that of population growth and demographics as the driver for building construction. Later on, we will consider the population growth / demographics concurrent challenges of resource utilization and waste generation.

According to the US Census Bureau International Data Base, the total world population at midyear for 2005 is estimated at 6.5 billion[65], and with very optimistic rates of growth, the population in 2035 is estimated to be 8.5 billion[66]. Other sources with a slightly different growth rate have the 2035 population estimated at 10.0 billion, while other sources using past and current growth rates show a doubling of the population to approximately 12.0 billion people by the year 2050. The characteristic J curve of exponential population growth shown in *Fig. 2.1* reflects the decreasing amount of time it has taken to add each additional billion people to our numbers.

Population growth is defined as the rate at which the number of inhabitants is increasing or decreasing in a given year, expressed as a percentage of the base population size. This percentage also takes into consideration the birth and death components of population growth. Most analysts predict a decrease in the population growth rate towards the end of the Century (see *Fig. 2.2*).

According to Davis (1999), when the world population was approximately 6 billion, there were between 1 and 2 billion buildings on earth. Using 6 people per household, Davis estimates

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[65] Billion in this study is per USA standard of 1,000 (one Thousand) Millions and not UK standards of one 1,000,000 (one Million) Millions.

[66] UN 2000 estimates (now considered obsolete) had the 2050 population between 7.9B (low) 10.9b (high) and 9.3B (most likely) with the caveat that they were dependent on fertility rates that are "what if" scenarios.

that housing accounts for approximately half of the total buildings in existence[67]. A household is defined as a person or a group of persons, who occupy a common dwelling, or part of it, for at least four days a week, and provide themselves jointly with food and other essentials for living. In other words, they live together as a unit. People who occupy the same dwelling but who do not share food or other essentials are enumerated as separate households. The dwelling unit type and quality ranges from a shantytown or slum cardboard and corrugated metal shelter, to a tepee, an igloo, a cabin, a high-rise apartment, a stand alone residence or duplex, a mansion or a palace.

Although the projections of net population growth (the first driving force) and assets in place are considered a soft number by most accounts (Haupt and Kane, 2000), by 2050 (in a span of 45 years) the total additional demand of housing units and correspondingly other building types may approximate 2 billion[68].

From 2050 to 2100 (in a span of 50 years) an additional demand may approximate 3-4 billion before predictions call for a decrease in the population growth rate (see *Fig. 2.3*). However the UN has issued a 2002 population report that has different long-term implications.

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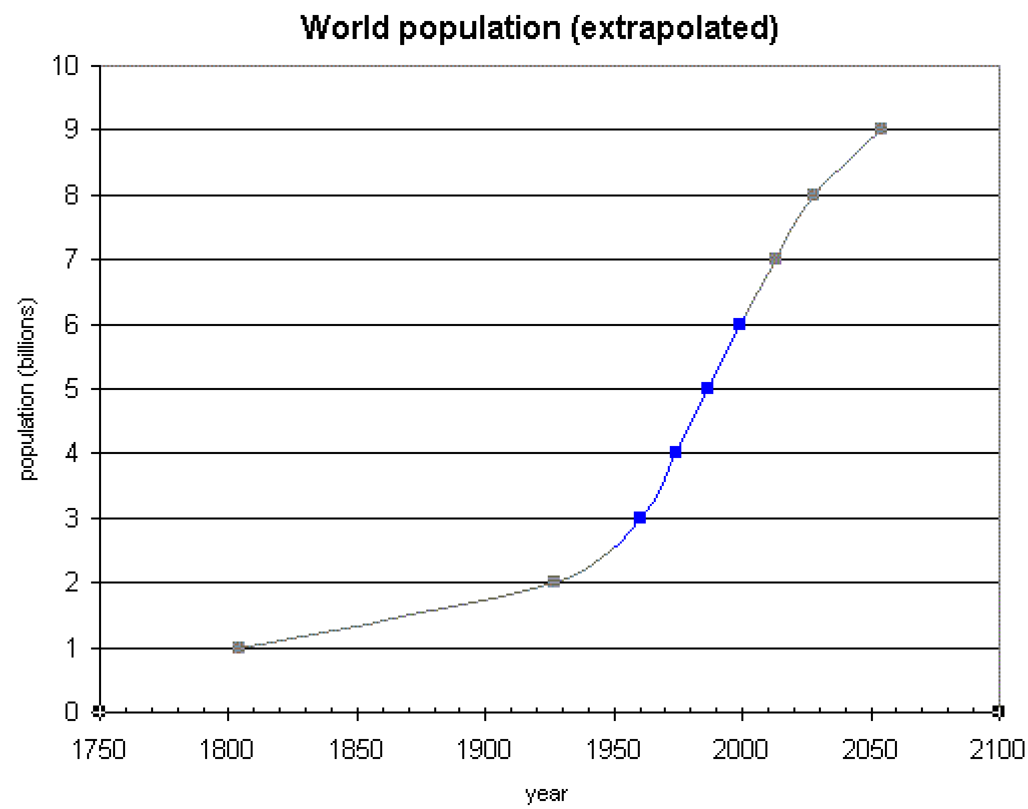
[67] Sebestyén (1998), on the other hand estimates that "between 1/3 and 2/3 of the total building volume in any particular country is (estimated) housing and the greatest investment sub-sector of the construction industry." Carassus 2004 estimates the size of existing global stock of built structure in 2000 at: global housing 43%, non-residential buildings 35% and civil engineering (infrastructure) 22%.

[68] This may be difficult to achieve considering that according to Sebestyén (1998) "the gross amount of housing available can be increased by a rate of only 2-3% per year, the net increase (i.e. new housing minus demolition) is even smaller. However this hypothesis has been overturned by the recent explosive increase in housing in China which is estimated at 33% for the years 2004 and predicted for 2005, although there is no indication of this level of increase is sustainable in the long run.



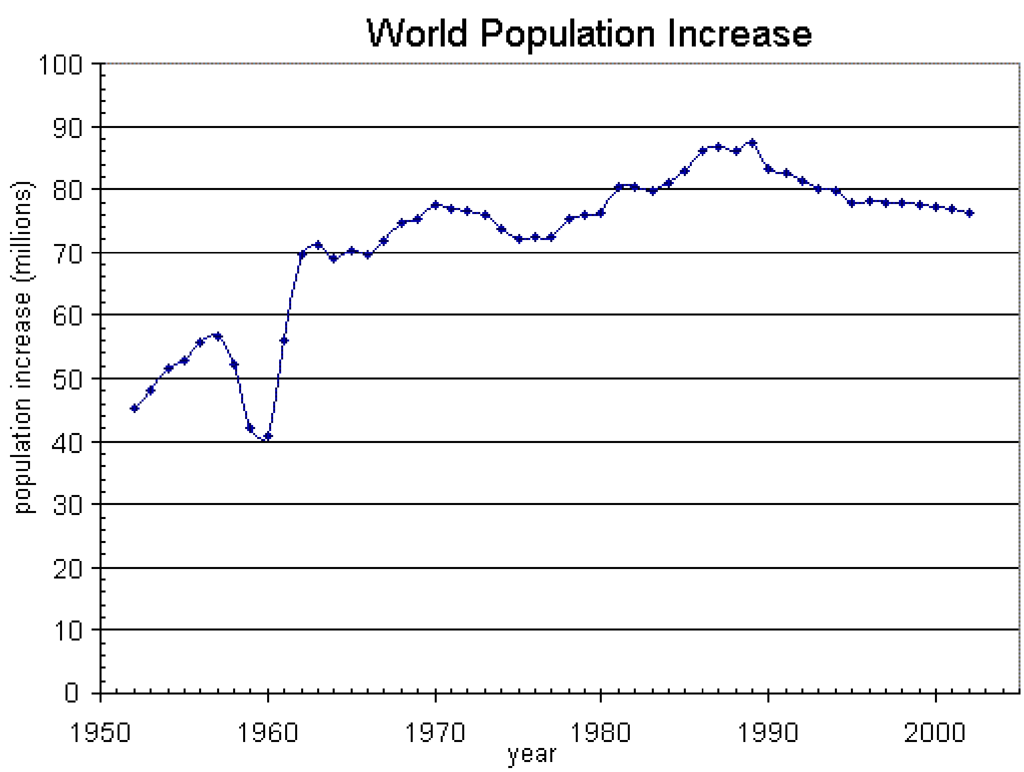


Fig. 2.1 Predicting Population Size

Wattenberg, B., 2005, states that prior to 2002 the UN assumed that worldwide population growth would slow to about 2.1 children per woman. New UN projections assume a TFR (Total Fertility Rate) of 1.85. The TFR of what the UN considers the More Developed Countries (basically the countries thought of as the "West" and Japan) is 1.6, well below replacement rate[69]. However recently, (Financial Times Sept. 13, 2005) countries such as Japan, France and Germany with severe declining population growth are considering implementing governmental economic programs to benefit families with children! How this will play in the predictions, pending governmental approvals and implementation, is to be seen and subject of additional studies. Pearce 2006 states that "work at the World Bank suggests that even quite low rates of population growth – a little over 1% per annum – can threaten sustainability."

For example, China's TFR dropped to around 1.8 because of the One Child Policy; Iran has dropped from a TFR of 7 in 1960 two just 2.1; Egypt has watched its TFR drop in half in the last 40 years to slightly above 3, and continues to drop; Brazil is now below the replacement level of 2.1. India has seen its TFR dropped from 6 to just over 3 in only a few decades and the trend is decidedly down. Demographers in Mexico expect the TFR to drop below replacement level in 2005. South Korea has gone from a TFR of 6.3 in the late 1950s to only 1.17; in 2003. Russia is at 1.1; Bulgaria is at 1.1; Japan is at 1.3; Germany is a 1.35. All told, there are 63 nations with a TFR is below 2.1.

[69] The US has the highest rate among all these countries at 2.0, while Europe as a whole is only 1.38. Using a slightly higher TFR for Europe, or 1.45, European population is expected decline from 728 million people today to about 632 million by 2050.

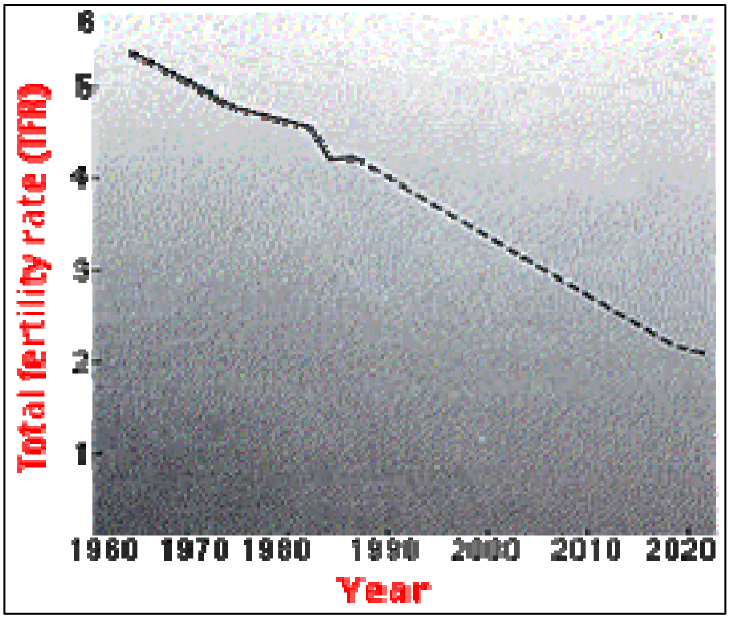


Fig. 2.2. Predicting Total Fertility Rate

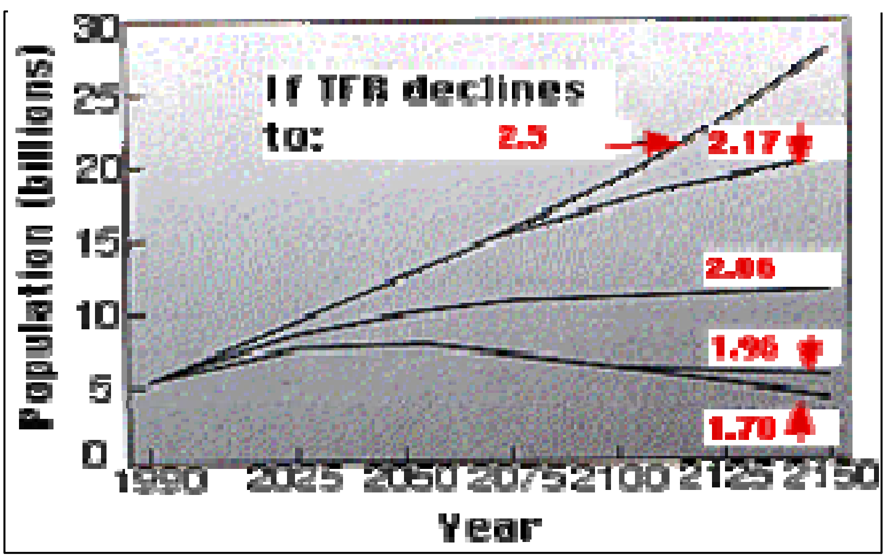


Fig. 2.3. Predicting Population per Total Fertility Rate (TFR)

Some of the long-term implications of this information, if correct, are:

1. Wattenberg (2005) makes the point that a nation whose population is not growing and is not increasing its tax base and economic base cannot continue to thrive. Consider America and Europe:

> "*The population in America today is roughly 300 million people. That is expected to grow to 400 million by the middle of the Century. Yet the TFR for the United States is 2.01 thus its growth comes entirely from immigration. A newly released Census Bureau report reveals that Hispanics made up half the US population growth of 2.9 million over the past year, and now constitute a seventh of Americans (some 41.3 million). The Hispanic growth rate (births and immigration) for the 12 months starting July 2003 was 3.6% compared with the overall population growth of 1%. Asians were next at a 3.4% rate, compared with 1.7% for native Hawaiians and other Pacific Islanders, 1.3% for blacks, 1% for American Indians and Alaska natives, and 0.8% for whites*."
>
> It is a far different world in Europe. Quoting from Wattenberg 2005: "*...consider Europe, according to [a UN publication called] "Replacement Migration." Today, Europe has more than twice as many people as the United States, but the whole continent takes in a net of 376,000 immigrants per year, about a third of the American number. In order to keep a total constant population, that European immigration number would have to rise to 1,917,000 per year, an annual increase of more than 500%. To maintain a constant age group of workers aged 15 to 64, the number of immigrants would have to rise to 3,227,000 per year, an annual increase of more than 900%. The UN also calculated what it would take to keep the dependency ratio constant, that is, the proportions of working age persons to those over age 65 and under 15. That would require an annual immigration of 27,139,000, an increase of more than 7100%. That is not likely to happen*."

2. Low birth rate will mean that there is and will be a high percentage of women who have no children at the end of their childbearing years[70].

3. The New Demography creates an imbalance between senior citizens and the rest of the population[71]. The aging population will have different housing needs and requirements.

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[70] Germany 26%, Finland 21%, United Kingdom 21%, Italy 19%, Netherlands 19%, and Canada 14%. The United States stand at 16%, up from 11% in the early 1970s.

[71] The Center for Strategic and International Studies notes that "for most of human history, until about a Century ago, the elderly (people aged 65 and over) never amounted to more than 2 or 3 percent of the population." (http://www.csis.org/gai/index.htm) accessed 4/25/05.

> "*There is an irony at work: a principal cause of the aging boom is a baby bust. The median age in America in 1950 was 30. By 2000 it was 35. In 2050, it is expected to be 40. In Europe in 1950, the median age of the population was 29 years. In 2000 it was 38 years. In 2050 it is projected to be 48. Japan had a median age of 22 in 1950, 41 and 2000, and an expected 53 in 2050. Seen another way, in 1950 just 8% of Europe's population was over age 65. 100 years later, in 2050, the projection is 28%*."

4. There is a stark contrast between retirement in Europe and retirement in America. Today it is traditionally 65 in the US. The retirement age (for Social Security benefits) was raised in the US in 1983 to 67, which will take full effect by 2022[72].

5. There are only about 175 million immigrants in the entire world. The United States has 20% of those, approximately 35 million[73].

> Wattenberg 2005 comments, "*While there are more immigrants than ever, there are nowhere near enough to deal with the massive structural magnitude of the problems at hand. A total of 3% of the global population are immigrants, but that amount, would not come close to providing substantial help for the looming pension shortfall in Europe. And despite the fact that scores of millions of ambitious people are ready to emigrate to places with a higher standard of living, even if it involves a high degree of danger, many of those places dislike newcomers. In a tough game, I think the immigrants will win. Someone has to empty those bedpans. And sooner or later (probably later), Europeans will have to learn how to accommodate pluralism*."

6. Only a decade ago, "experts" predicted that the world population would grow to 14 billion. Now, the median projection is 9.1 billion based upon a 1.85 TFR by 2100. If that TFR were to stay the same, global population would fall from a high of about 9 billion to 2.3 billion people by 2300. Wattenberg 2005 concludes, if, as seems likely today, TFR rates continue to fall throughout the world, it is quite possible that total world population peaks at slightly fewer than 8 billion people in the middle of the Century, and drops to 5.5 billion by the end of the Century.

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[72] The following are examples of the average retirement age for men in Europe: Belgium, 58.1; France, 58.8; Germany 61.0; Italy and the Netherlands are slightly under 60; United Kingdom, 62.9; in Switzerland, 64.5.

[73] Russia is in second place with 13 million (although many of them are Russians returning from the former Soviet Republics) and Germany is third with 7 million.

In the final analysis, regarding the hypothesis of this study, there are three major insights that can be obtained from current data and predictions: Firstly, there is a continued population growth in this Century following the 'J' curve before a predicted and hopeful tapering off and becoming an 'S' curve; Secondly, most countries with a lowering TFR will be looking at immigration to maintain economic growth; Thirdly, some countries with major population that are not prone to migration or immigration are on a fast track towards higher standards of living. These scenarios are demographic forces with direct impact on construction.

2.2.1 Population Numbers and Resource Consumption

Population 'need' and 'want' for shelter as well as other ancillary buildings drives the demand for construction and thus resource utilization as well as waste production. This portion of the study focuses on resource consumption in the process of transforming materials, processes such as services into a finished product, the building.

Regarding the first driving force, net population growth, Watt (2000) of the University of California-Davis 1999, stated that he and about 100 other scholars "believe that energy (consumption) and number of births will be the two key variables in determining the character of the future." To this statement, this study adds high-grade metallic ore resource depletion and climate change (with possible catastrophic consequences[74]) as concomitant forces directly affecting the character of the future.

In 1992 the National Academy of Sciences and the Royal Society of London issued a statement (quoted by Speth 2005) that "*if population growth continues at currently predicted*

[74] According to Sebestyén (1998) climate models indicate an increase in green house gases in atmospheric air is changing the world's climate, which will lead to stronger winds in some regions and weaker winds in others. However that is not the limit to the extent of fluctuations. Other predictions are for increase in number and strengths of hurricanes, typhoons, cyclones; rainfalls of 100 year records more frequently; possibility of northern and southern hemispheric ice age conditions while at the same time record heat waves in the tropics (the year 1998 is the warmest year in meteorological record – world wide and others.

levels, much of the world will experience irreversible environmental degradation and continued poverty." This is attributed to both people overpopulation and over-consumption. People overpopulation is defined as when the environment is worsening because there are too many people placing a demand on resources to meet basic needs. Over-consumption occurs when people in a population consume too large a share of resources. According to Raven and Berg 2004, "both overpopulation and over-consumption cause pollution and degradation of the environment."

The link between exploitation of resources, wealth and population is the subject of numerous studies. Ludwig et al. (1993) observes that the history of resource exploitation is remarkably consistent: 'Resources are inevitably overexploited', often to the point of collapse or extinction. This exploitation, adapted from Ludwig, has the following common features:

1. Wealth or the prospect of wealth generates the power that used to promote 'unlimited' exploitation of resources.
2. Large levels of natural resources mask the effects of overexploitation. Initial extractions or uses are not indicative of resource depletion until the scarcity becomes severe or irreversible.
3. The processes of using the resources usually lack control and replicate models therefore the extinction of one resource location is interpreted as the need to move to another.
4. Trial and error determine optimum levels of exploitation (if at all, and in the case of mineral consumption not at all).
5. The 'more' immediate prospect for financial gain, the greater wealth or prospect for wealth generates greater power to facilitate unlimited exploration.

Ludwig is concerned that resource managers may be resorting to 'magic' substituting the word sustainability for reality. "*As long as human desires are unlimited, we shall invent magical theories (such as sustainability) in an attempt to reconcile the irreconcilable*." If sustainability is to be more than a magic word, he feels it is essential to:

- Halt human population increase
- Reduce per capita human consumption resources

Thus the question is not 'whether' but 'when' the foreseeable permanent fossil and high-grade mineral ore depletion will occur. Likewise the question is not 'whether' but 'when' will humanity experience long term climate change (Arnell et al. 2004) producing unintentional and unforeseen catastrophes at a global scale. Watt 2000 continues, "*This next paralyzing and permanent shock will not be solved by additional discoveries, redistribution patterns or economic cleverness because it will be a consequence of pending and inexorable depletion of the worlds' conventional resources. Few economists, as of this date, can bring themselves to accept that resources are geological finite*[75]."

The challenge of population growth by itself puts pressure on building construction's capacity to satisfy the numerical demand. In previous years this type of demand would be met through an increase in building activity, components or unit manufacturing, and industrial productivity. Nonetheless, the population increase challenge is still concatenated with other challenges, such as the above mentioned climate change through waste generation and the previously termed third driving force, an increase in population seeking a higher standard of living (over-consumption) which is the next challenge to consider.

2.2.2 Standard of Living Mobility

A second driver in housing demands relate to the demographic movement of a population from needs to wants, from developing to developed[76] in a drive to improve the standard of living, accompanied in this case with bigger and more sophisticated housing accommodations. The goal of technology is human freedom from needs and geared towards wants. This human freedom

[75] Deffeyes 2005, states "as of 2003, there was no major underutilized oil source left on the planet." According to some geologists, as reported by Williams 2005, "we have discovered 94% of all available oil. Debate on the depletion of fossil fuel is well advanced and documented since it critically affects the General Economy which has been based primarily on this source of energy since the onset of the Industrial Revolution. This study uses fossil fuel depletion as an example, but will not focus on this example. Similar statements will be provided in this study regarding high-grade mineral ore exploration and consumption.

[76] Improving standards of living increases consumption but generally is considered to lower the rate of births down the generational lines.

through technology is achieved through material mastery in order to escape from the limitations of nature (Mitcham 1994). This "improving quality of life[77]" driver is expected to continue the demand of new construction well into the future. However, these projections do not take into consideration additional demand due to population shifts (immigration) from political, economic and catastrophic causes (a third driving force) that complicate and expedite the demands.

2.2.3 Brief Analysis of China's Population and GNP growth

China is an interesting case study regarding increase in standard of living for several reasons: (i) at the present time it has close to zero population growth; (ii) its land area approximates that of the United States[78], thus eliminating two variables in a comparative exercise; (iii) because its recent economic growth explosion and accelerated building construction program has global repercussions and is well documented; (iv) because this accelerated growth is placing economic and structural demands on global resources.

Case in point of very large standard of living mobility[79] population (the second driving force): China had a population of 1.3 Billion in 2004 and the economy experienced a conservative 9.5% real domestic growth in 2003 and 2004[80], which translates to a doubling of the economy in approximately less than 7 years using a conservative 10% rate of growth (69/10). This information checks with published data indicating that between the years 2000-2004 the Chinese economy grew 53% (a 50% increase in two years, which approximately corresponds with a doubling of the economy in four years, a remarkable feat considering the size of the

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[77] Raven and Berg (2004) state that "it is impossible to quantify the 'carrying capacity' of earth for humans in any meaningful way, in part because our impact on natural resources and the environment involves more than the number of humans. To estimate 'carrying capacity' for humans we must make certain assumptions about our 'quality of life' that is standards of living, lifestyles.

[78] China total area is 9,596,960 sq. km. compared to the US 9,629,091 sq. km.

[79] China by the numbers (CIA Factbook, International Monetary Fund World Economic outlook, Squire Sanders & Dempsey and the China National Interior Decoration Association).

[80] Allen, et. al, 2002 estimate China's real domestic growth rate for 2004 to approach 10.7%.

economy to start with). A more recent estimate from the Organization for Economic Cooperation and Development, using Chinese government figures (released September 16, 2005) states that China's economic transformation is well placed to maintain its average of 9.5% growth rate of the last two decades for "some time". This translates into becoming the worlds' biggest exporter and the fourth largest economy by 2010.

Recent publications (FT 10/06) are posing the strong probability that China may become the worlds' largest economy by 2010 or sooner. FT 10/20/06 reports that China has achieved four years with more than 10% economic growth (the previously reported percentages have been updated). Although this growth is fueled mainly by trade surplus and foreign investment expansion, a higher percentage is being generated every year by domestic consumption. China's own engine of growth is primed while inflation remains low at 1.5%. The epic scale of China's commodities and fossil fuel needs have begun to be fully appreciated only in the last three years. The same FT reports that in 1993 China became a net importer of oil. In 2003 it overtook Japan, and in 2006 it is second to the United States as an importer of oil. The rate of imported oil continues to raise and in 2030 it will import 80% of its projected oil needs that amounts to the total oil consumed by all other nations combined.

Kynge (2006) provides an in-depth analysis of the forces behind china's growth, the potential of an extremely large population with barely minimum global poverty wages with the advance tools of the Industrial Revolution, capable of an unheard off productivity across all segments of manufacturing and even service industries. With the need to create 24 million new jobs each year just to keep with population growth, is a nightmare of epic proportions. Aging population is a serious topic that Kynge also addresses. China has an increasingly aging population that may never see prosperity.

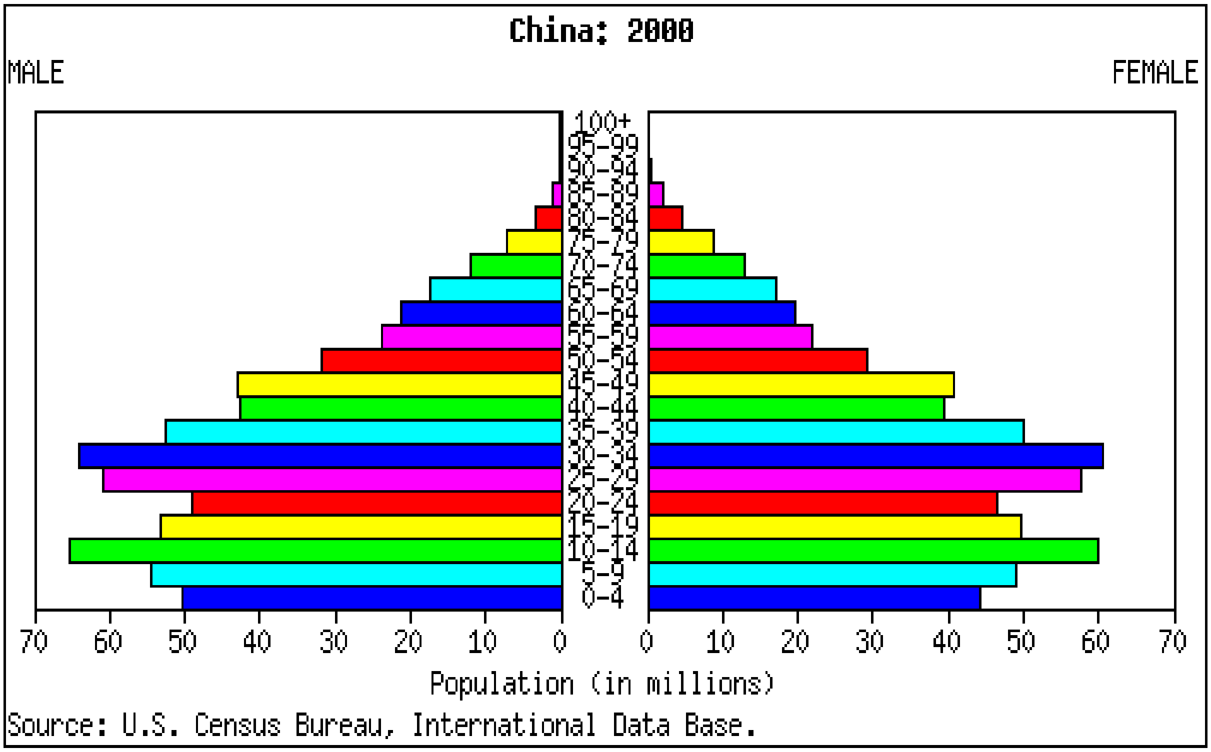


Fig. 2.4 China 2000, Population Estimates

China in 2004 is reported to have brought 70,000 Mega watts of new capacity on-line that year, the amount almost equivalent to Great Britain's entire power generating capacity, and expects similar increases in 2006 and 2007 (Financial Times August 10, 2005 by Richard McGregor, Beijing). China's booming economy led to an increase in power consumption of about 15% in 2004 and 13% in the first six months of 2005. About 75% of this new power is consumed by new users. Approximately 80% of this power is generated by coal, although nuclear power plants, now under construction, will affect the ratio. To put this in perspective, the same sources state that China still has more than 400 million inhabitants without power, approximately double the size of the United States population (Morrison, Dyer, FT 5/10/06).

Even more, in a country that the net population growth in recent years is zero (*See Fig. 2.4 and Table 2.1*) growth in new housing construction was 33% in 2004 approximately and expected to continue in the foreseeable future[81]. This translates to a doubling of new house construction in approximately less than two years! The price increases (doubling of mineral resources and fossil fuels) experienced globally (see sample below) in the last two years (2003-2004), the related demands on resources are being attributed by economists to the first doubling of this building construction economy. Economies contain two sorts of activity: tradable (manufacturing and services that can be supplied at a distance) and non-tradable (haircuts, childcare, construction, and so on.) With economic development, such as in China and India, productivity in the tradable tends to rise faster than in the non-tradable. In China, the tradable of the last decade are the economic forces (like the 2006 soaring account surplus) pushing the considerable growth in the construction non-tradable.

At its founding in 1949 the People's Republic of China had a population of 540 million. Only three decades later its population was more than 800 million (almost doubling in 30 years). This enormous population increase created a strong population momentum that still drives population growth despite rapidly declining fertility in the late 1970s and 1980s. In 1995, China's population reached 1.23 billion (almost doubling in 15 years). In its most recent (medium variant) projection, the UN Population Division estimates that China's population will increase to 1.49 billion in 2025 and then slightly decline to 1.48 billion in 2050 (US Census Bureau, International Database, 2005). Currently, FT 10/06 reports that China has relaxed the one child rule and is adding a net of 7M people per year.

[81] In contrast US annual production of new homes (National Association of Realtors) was 7.02m in 2004 and predicted to be 6.89 m in 2005, a net decrease of approximately 1.85%.

Table 2.1 China Demographic Indicators

Years:	2005	2025
Births per 1,000 population....................	13.0	11.0
Deaths per 1,000 population....................	7.0	8.0
Rate of natural increase (percent).............	0.6	0.2
Annual rate of growth (percent)................	0.6	0.2
Life expectancy at birth (years)...............	72.3	77.2
Infant deaths per 1,000 live births..........	24.0	11.0
Total fertility rate (per woman)...............	1.7	1.8

Midyear Population Estimates and Average Annual Period Growth Rates: 1950 to 2050
(Population in thousands, rate in percent)

Year	Population	Year	Population	Period	Growth Rate
1950	562,580	2005	1,306,314	1950-1960	1.5
1960	650,661	2006	1,313,974	1960-1970	2.3
1970	820,403	2007	1,321,852	1970-1980	1.8
1980	984,736	2008	1,330,045	1980-1990	1.5
1990	1,148,364	2009	1,338,613	1990-2000	1.0
2000	1,268,853	2010	1,347,563	2000-2010	0.6
2001	1,276,882	2020	1,430,533	2010-2020	0.6
2002	1,284,276	2030	1,461,528	2020-2030	0.2
2003	1,291,496	2040	1,454,619	2030-2040	0.0
2004	1,298,848	2050	1,424,162	2040-2050	-0.2

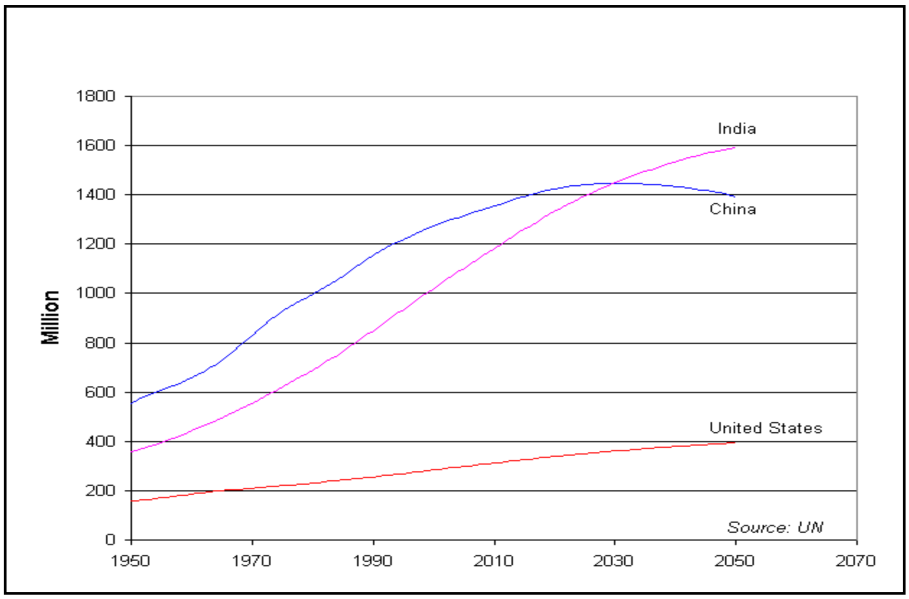


Fig. 2.5 Population by Country, 1950-2004 with projections to 2050 (India, China and the

This is equivalent to a population increase of roughly 261 million people between 1995 and 2025 and a population decline of 3.7 million between 2025 and 2050. In other words, during the three decades between 1995 and 2025 China's population will increase by a number of people roughly equivalent to the total population of the USA on a total area that is equivalent to that of the US, see *Fig. 2.5*. However, the population and densities are considerably different: China population estimate (2005) is 1,306,313,812 and the US is 295,734,134 translating into a density of 136 humans per sq. km. for China vs. 28 humans per sq. km. for the US. In other words, China has approximately five times the density of the United States.

China's future population growth is a product of past growth. The average number of children per woman has been below the replacement level of 2.1 since the mid-1980s. Most recent estimates from the State Statistical Bureau assume that current fertility on a national average is at 1.85 children per woman. In cities, the fertility was estimated at 1.43, in towns at 1.58, and in rural counties at 2.00 children per woman. Whatever population growth we see in the future will be caused not by high fertility, but by the "population momentum" of China's young age structure. Population growth and density is a legacy of the 1950s and 1960s, when China's fertility was quite high and mortality had already declined. Consequently, China now has a large number of young adults of reproductive age. Their number will actually increase until 2015. This growing number of potential parents is the reason the number of births will remain high even if fertility remains at the current low level.

China's population planners can do nothing about this structural increase. The problem they face is keeping fertility at the current low level. However, with China's economic modernization, this may be an uphill battle, because in a more liberal society many Chinese might not accept the government's strict one-child family policy[82]. This policy has already been loosened for parents who were single children themselves, for farmers, and for ethnic minorities. In fact, most population projections for China assume that fertility will increase slightly to the replacement level of 2.1 children per woman. Policymakers in China are of course aware of this challenge. The family planning program still has very high political priority, even under the most recent political administration.

On the other hand, there is a secular trend toward small families among younger couples in urban areas. Surveys have documented a lifestyle change among those sections of the urban population that have benefited most from China's economic development. They prefer later marriages, later first births, and increased birth spacing, not only because these decisions are promoted by the family planning program, but also because they make it easier to improve one's education or pursue a career. As in many other developing countries, fertility in China will probably decline with increases in prosperity and education. Thus, there are two opposite trends: On one hand, the liberalization of society is "weakening" the family planning program, which might lead to an increase in fertility, on the other hand, economic development is promoting a lifestyle change associated in developed countries with lower fertility. China's future population growth will depend on the balance of these two factors.

Allen et al. (2002) discusses China's recent dynamic economic growth[83]. The factors that influence China's growing economy seem to defy the factors usually associated with economic growth. "*Despite its poor legal and financial systems, China has the largest and one of the*

[82] The above data does not consider the synergy of possible birth rate growth due to a population rebellion as a way to defy governmental policy and the possibility of a population boom due to 'new found wealth and status' a la post WWII in the USA that caused a baby boom generation.
[83] David League writing in the International Herald Tribune, June 4-5, 2005 "the total for rent Real Estate deals in the first quarter of this year (2005) exceeded $300 B, according to Government figures."

fastest growing economies in the world." The factors that seem to influence China's economic growth include China's culture, international trade status, and unmatched human resources pool.

Instead of legal and financial systems in the formal business sector, the success of China's economy seems to be based more on substitute cultural factors such as reputation and relation in the informal sector. "China's legal system is underdeveloped relative to most countries; including other major developing countries….Our conclusion is that there exist very effective, non-standard financing channels and corporate governance mechanisms to support the growth of the informal sector. Our evidence suggests that these informal channels and mechanisms are based on reputation and relationships, and they can substitute for and do better than standard channels and mechanisms."

Secondly, and related to the first point, China enjoys one of the most fruitful trade statuses in the world. "*China's rapid growth only started in 1979 when it opened its door to the outside world*." As a result, "*In terms of PPP*[84]*-adjusted GNP figures in 1999, China is more than twice the size of India, the second largest country in the list. While in terms of the growth of both PPP-adjusted and population-adjusted (per capita) GNPs during 1990-1998, China's annual growth rate of 10.7% is almost twice as high as that of Argentina, which has the second highest growth rate during the same period. With the recent entrance into the WTO and the large potential market it can provide, China will play an increasingly significant role in the world economy*."

A deeper understanding of the emergence of China and India as global powers in a continually deteriorating global environment is essential. The industrialized world practice of unbridled consumption and pollution and cleaning up later testifies that a developed economy

[84] PPP is Purchasing Power Parity

has not succeeded in containing its impacts: it remains steps behind the problems it creates. Furthermore, developed and now developing countries externalize the growth problems to others.

	Table 2.2 World Countries GDP (2005 estimate)		
Rank	**Country**	**GDP (purchasing power parity)**	**Date of Information**
1	**World**	$ 60,710,000,000,000	2005 est.
2	**United States**	$ 12,360,000,000,000	2005 est.
3	**European Union**	$ 12,180,000,000,000	2005 est.
4	**China**	$ 8,859,000,000,000	2005 est.
5	**Japan**	$ 4,018,000,000,000	2005 est.
6	**India**	$ 3,611,000,000,000	2005 est.
7	**Germany**	$ 2,504,000,000,000	2005 est.
8	**United Kingdom**	$ 1,830,000,000,000	2005 est.
9	**France**	$ 1,816,000,000,000	2005 est.
10	**Italy**	$ 1,698,000,000,000	2005 est.
11	**Russia**	$ 1,589,000,000,000	2005 est.

Today's industrialized mega-countries (such as the USA, Europe, China and India) are in a highly capital-intensive (see Tables 2.2 and 2.3); social divisive; material and energy-intensive general economy where critical investments to equity compete with costly environmental and sustainable growth. For example FT 10/20/06 reports that China has seven of the world's ten most polluted cities, eighty percent of the epic increase in electricity is generated by coal, the dirtiest source, within a few years, China's coal fired energy sector alone will turn it into the worlds' leader in green house emissions. In 2004, the US produced 6,000 million tons and China produced 4,300 million tones of Carbon Dioxide. A graphic projection of EIA Comparison of US and China Carbon Dioxide Emissions indicates that the year 2006 could be a milestone when China surpasses the US in green house emission generation (see Table 2.3).

Table 2.3 United States and China Carbon Dioxide Emissions (millions of metric tons) Comparative Table with Projections into 2005, 2006 and 2007

Country	**2003**	**2004**	**2005**	**2006**	**2007**
United States	5,807.71	5,912.21	6,016.70	**6,121.20**	6,225.70
China	3,897.98	4,707.28	5,516.58	**6,325.89**	7,135.19

Source: EIA table found in http://www.eia.doe.gov/pub/international/iealf/tableh1co2.xls

The adverse impact of growth manifested in un-historical rates of resource consumption and emissions generations when not tempered can be disastrous. However China and India cannot afford to follow the industrialized countries' model of waste and pollution followed by clean up and efficiency.

The environmental, green and sustainable movements of developed countries that happened after and during a period of wealth generation, waste and emissions generation argue for containment of waste and emissions but do not have the foresight and ability to argue for the re-invention of the waste and emissions paradigms. Sustainability is understood by the limits of existing paradigms of consumption, waste and emissions: trade, containment, and sequestration. The answers to change in this worldview are intractable and impossible unless the questions are re-invented, a new paradigm is developed, and a more accurate worldview is achieved.

2.2.4 Ecological Footprint Concept

Wackernagel et al. (1997, 2002; EEA 2005) and colleagues compared the economic impact of individuals in what he termed the 'ecological footprint' an average amount of productive land

and ocean needed to supply that person's food, energy, water, housing, transportation and waste disposal. In a developing country the ecological footprint is about 1 hectare (2.5 acres) and in developed country it is 9.6 hectares (23.7 acres). This concept highlights what happens when a country, which in this case is China (and in the near future India) follow the western economic model of consumption.

Table 2.2 (Brown 2005b; Venetoulis and Talberth 2005) are graphical representation of

Table 2.4 Comparative analysis of Key Resources in the US and China in 2005

Annual Consumption and Use of Key Resources and Consumer Products in the United States and China, Latest Year				
Commodity	Unit	**China**	**United States**	
Grain (1)	Million Tons	**382**	**278**	
Meat (1)	Million Tons	**63**	**37**	
Oil (1)	Million Barrels per Day	**7**	**20**	
Coal (2)	Million Tons of Oil Equivalent	**800**	**574**	
Steel (2)	Million Tons	**258**	**104**	
Fertilizer (2)	Million Tons	**40**	**20**	
Cellular Phones (2)	Million in Use	**269**	**159**	
Television Sets (3)	Million in Use	**374**	**243**	
Refrigerators (4)	Million Produced	**14**	**12**	
Personal Computers (5)	Million in Use	**36**	**190**	
Automobiles (2)	Million in Use	**24**	**226**	
(1) Data for 2004.				
(2) Data for 2003.				
(3) Data for 2000.				
(4) Data for 2001.				
(5) Data for 2002.				
Source: Compiled by **Earth Policy Institute**, February 2005, from USDA, IFA, DOE, BP, IISI, ITU, UN, and Ward's. For detailed data over time and full sources see tables below.				

an enlarging footprint when a developing country follows a developed country model and surpasses that country as the world's leading consumer of most basic commodities like cement, grain, coal, steel, meat, cellular phones, televisions, refrigerators, etc. At the current economic growth rate, China's projected population of 1.45 billion in 2035 will have surpassed the US annual income per person of $38,000 per year (currently it is $5,300).

To give a sense of the magnitude and the scale of our current global trend, with the current models of consumption and the materials and energy sources available, if China were to consume oil at the rate that the US does, China would need 99 million barrels of oil per day (a figure expect to be reached in 2030) when the current global production is approximately 79 million barrels of oil (Brown, 2005a). This same principle applies to building construction materials and resources. That is a sobering size of an ecological footprint (Venetoulis and Talberth 2005); legacy of the systems humanity has created.

Of particular interest in *Figs. 2.5 & 2.7* is the shape of the curves in the oil (Deffeyes, 2005) and automobile consumption in China pointing to a "J" curve of significant import.

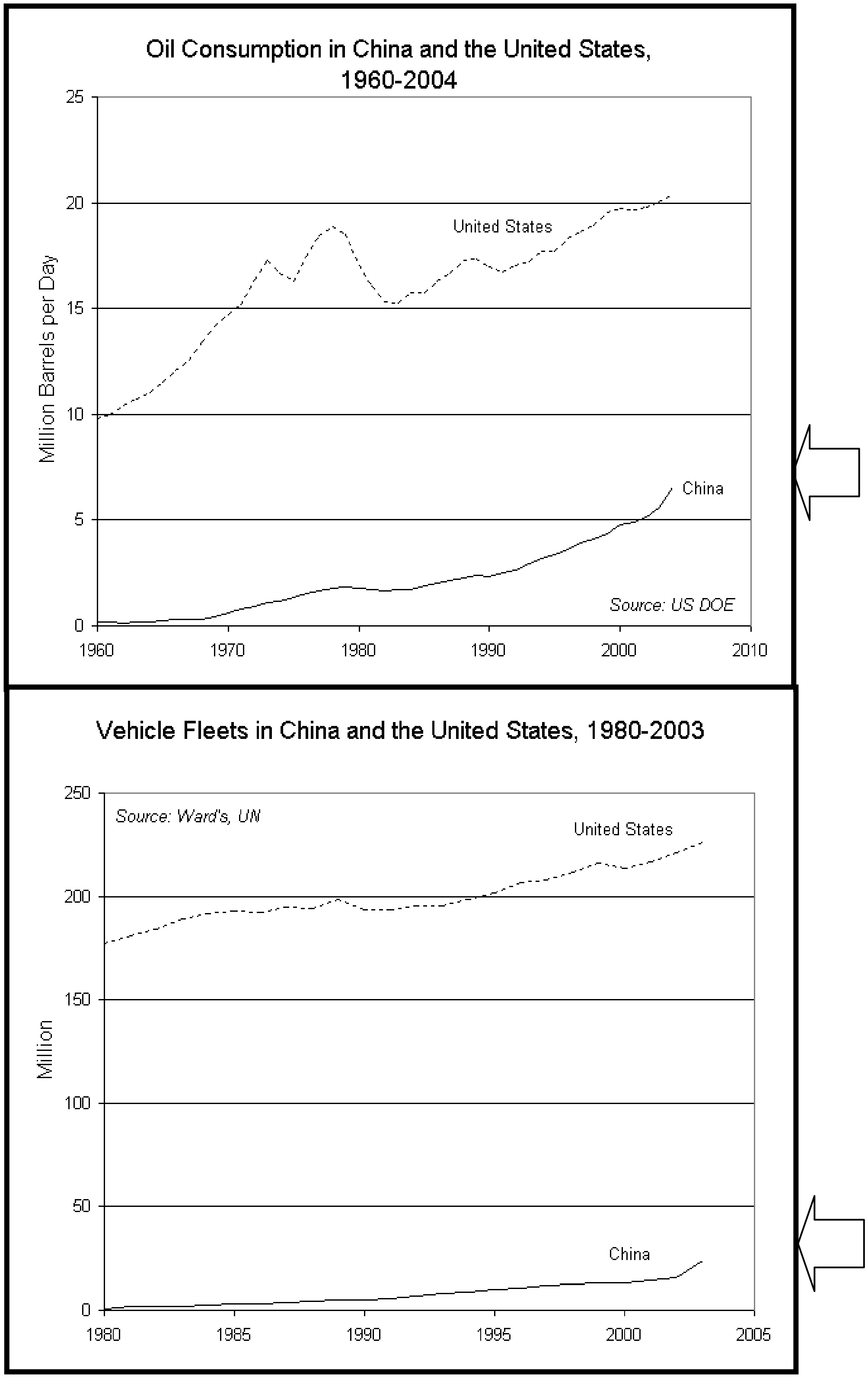
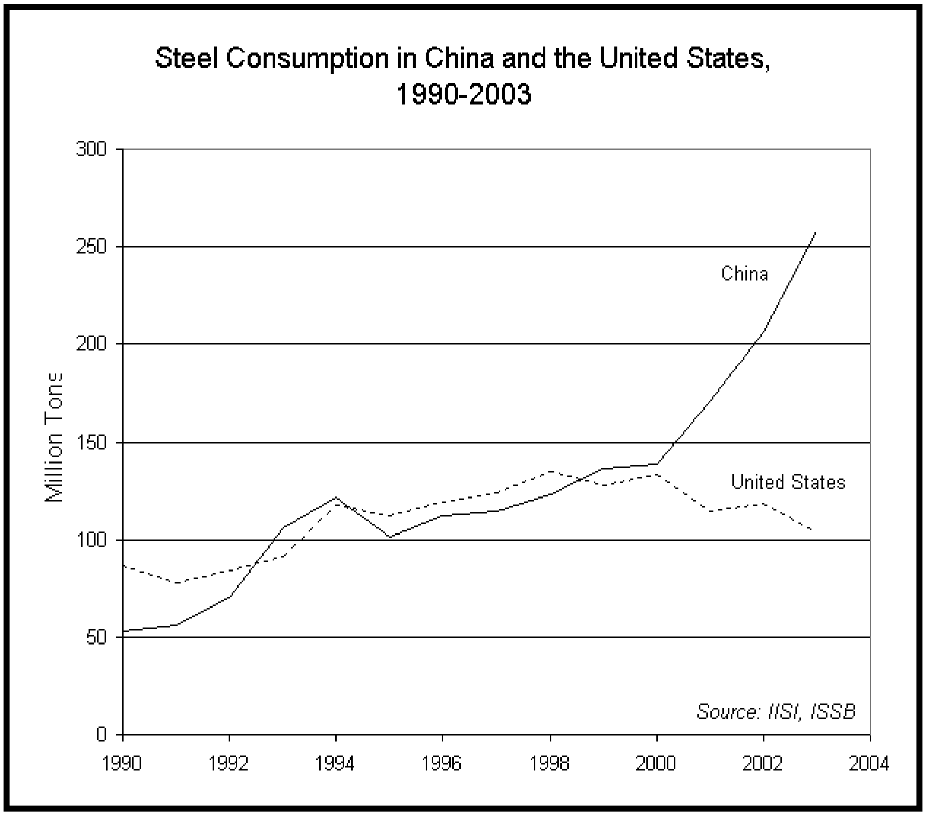


Fig 2.6 Oil and Vehicles in China and the United States 1960-2004. Arrows indicate the start of the "J" exponential growth.



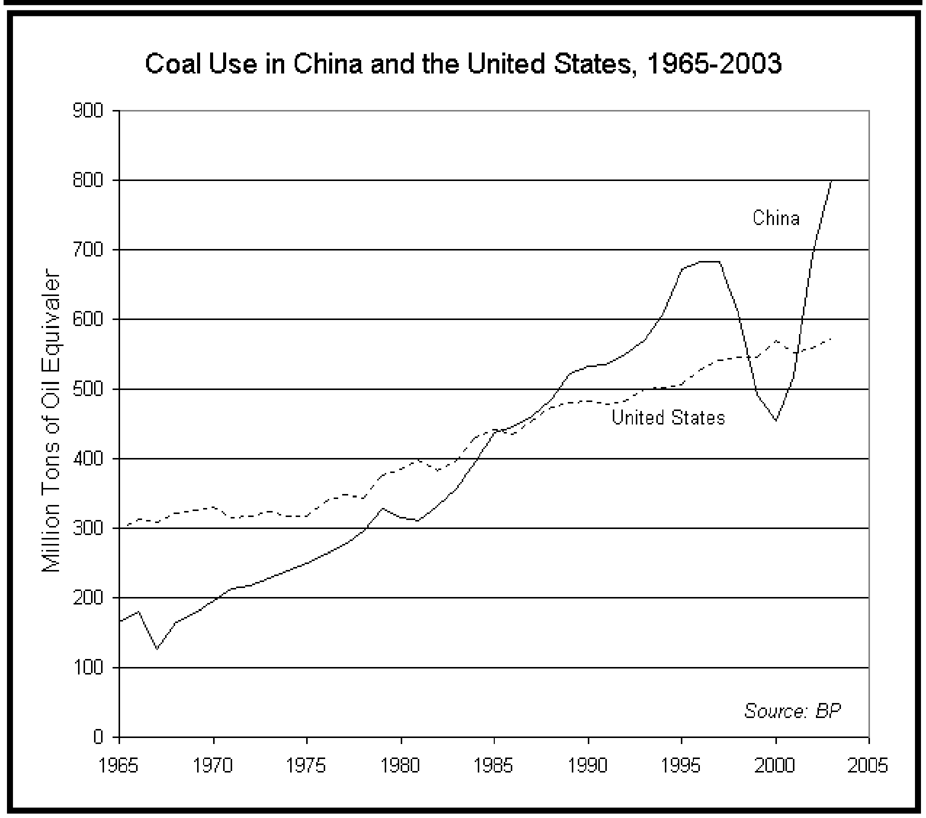


Fig 2.7 Steel and Coal use in China and the United States 1990-

2.2.5 Differentiation of Needs and Wants

In order to understand this migration in standard of living, we must investigate the philosophical drivers of needs and wants. The drivers of the shift in the standards of living between developing and developed countries are understood through the differences between human needs and wants. McHale (1972, 1978) is a classic in his time presenting the state of the art of quantifiable side of needs assessment. McHale warns, though, that in many areas of human concern, (a) even where we have become richer in numerical data, we remain somewhat poorer in the meanings we can attach to them and (b) any assessment of basic human needs is essentially normative in character. "*We should not therefore allow the numbers themselves to assume an authority and sacrosanct quality which is unwarranted by their margins of error, their degrees of aggregation and the highly variable character of their standards of measuremen*ts".

McHale suggests the unit household concept as a useful unit of measure, which can be made operationally specific to different local situations. The unit household mode also can be extended to the unit community, to extended kinship networks, and other groups or settings more applicable in different social and cultural settings. Adequate shelter, housing, is one of the core human needs, since so many of the other basic needs are satisfied in relation to the household or home – food storage and preparation (energy consumption), primary health maintenance, child care, early socialization (sense of belonging), education, storage of clothing, sleeping and resting, and of course shelter from inclement weather.

McHale (1972, 1978) detailed study in classifying nations in comparative development terms, or according to levels of living analyzed by professionals, have separated the world into two divisions of developed or developing and have lately introduced third and fourth world categories. They admit that within this there is considerable variance and gradation, ending up with a scale from A through E. The 1979 study includes in group A (developed) USA and USSR along with 20 other countries; Group C (developing) China along with 52 other countries; and in Group E (under-developed) India along with 36 other countries. A household of five persons per unit was chosen as typical of a medium size family unit. For our study, we are considering small, medium and large family sizes; thus take an average household family size of six persons per family or household unit. For the purpose of this study, we have adopted the simplified developed and developing structure which conveys the transition from one scale to another. For a philosophical meaning of needs and wants, then, we turn to Max-Neef and Maslow.

Max-Neef (1991) has a basic conceptual idea that humans have a definite and limited set number of needs that all must be met in order to survive and that none of these needs can be substituted for one another. However, Maslow (1968; Gwynne, 1997) believes, that there is a hierarchy of needs, where higher needs cannot be met fully until lower needs have been met. Maslow, 1943 (Maslow, 1968) takes a Darwinist approach to his scheme of needs based on his studies of primates, which is transferable to humans. Max-Neef (Gips, 1999) however takes the complexity of human beings and of satisfiers that in his view crosses over the neat boundaries that Maslow demarcates on human needs.

Max-Neef presents a definition of human needs and the consequences that arise when these needs are not satisfied. Max-Neef's main concept of needs is that the basic human need are "finite, few, and classifiable." There are nine essential human needs that have to be met in order to be 'satisfied': subsistence, protection/security[85], affection, understanding, participation, leisure, creation, identity/meaning and freedom. McHale's (1978) study separates biophysical

[85] Sebestyén (1995) observes that "the earliest buildings served primarily residential (sheltering/safety) purposes."

(of what is defined as basic, or first floor needs of food health, shelter and clothing) and psychosocial (defined as second floor and representing a much wider range of needs encompassing education, employment, communication, mobility, recreation, and security). McHale's (1978) study has three levels of need: (a) Deficiency Needs are those threshold needs, mainly biophysical, which must be met to maintain survival, that is, first floor needs. (b) Sufficiency needs are those that should be met to maintain living standards at some desirable level (undefined here) well beyond marginal survival. (c) Growth needs go beyond the sufficiency standard and allow the movement from material sufficiency to enjoyment of non-material ends and aspirations. Both sufficiency and growth needs constitute the second floor in the needs hierarchy presented in McHale's study.

These needs are present in all humanity and they are the "same in all cultures and historical periods." Max-Neef contention is that the only thing that changes from culture to culture is the means by which people satisfy these needs. However, these needs are not substitutable and a satisfier can fulfill more that one need at a time.

The satisfiers that are used to placate these needs differ greatly, and may be done straightforwardly, or in an indirect manner. The difference between the needs and satisfiers is that a need is a basic human requirement. For example, people usually confuse food and shelter as needs, but according to Max-Neef these are merely satisfiers that contribute to fulfillment of the need of subsistence and security, respectively. It is the particular type of choice of satisfiers used to fulfill any of the nine needs that can define a culture. **C**ultures as well as their means for satisfying these needs vary.

In addition to this concept of needs and satisfiers, Max-Neef also delves into the term "poverty." He defines poverty as the lacking of any of the nine needs: "Any fundamental need that is not adequately satisfied reveals a human poverty." Therefore, a person lacking in affection, or freedom, reveal (according to Max-Neef) human poverty. Finally, Max-Neef includes an after statement of sorts in his arguments stating that all of the needs of an individual must be met, to avoid poverty, defined by Pearce (2003) as lacking of access to capital (see also nCRISP 2004).

In contrast, Maslow's main theory of needs is that there is a hierarchy of needs and humans are motivated by unsatisfied needs. His main argument is that there are lower needs that need to be met first before the higher needs, and before the human can be fully satisfied. It is when these lower needs are not satisfied that 'poverty' is experienced. The lower needs that Maslow views as a requirement for all humans to survive are: physiological, safety, love, and esteem. He also refers to these as deficiency needs because if they are not met, we cannot move towards growth and self-actualization. The primary difference between Maslow and Max-Neef's theories on human needs is the fact that Maslow sees his needs as steps, each existing on different planes and is prioritized, whereas Max-Neef views human needs as an all or nothing shot at fulfillment that is 'satisfaction'.

Very basic and broad definitions of human wants are defined as everything acquired or sought after by humans that are not a human need. Accordingly Max-Neef and Maslow define human wants differently. Max-Neef defines 'wants' as anything beyond needs. On the other hand, Maslow defines 'wants' for each individual over time based on going beyond the satisfaction of needs at a certain level. According to the views of these two philosophers and interpretative literature, a 'want' is superfluous, in relation to needs, and a person could survive without satisfying that want. Needs and Wants (that can be translated in similar concepts to capital, footprint, etc) are the modifiers of Population into Developing or Developed Status (see

Fig. 2.8).

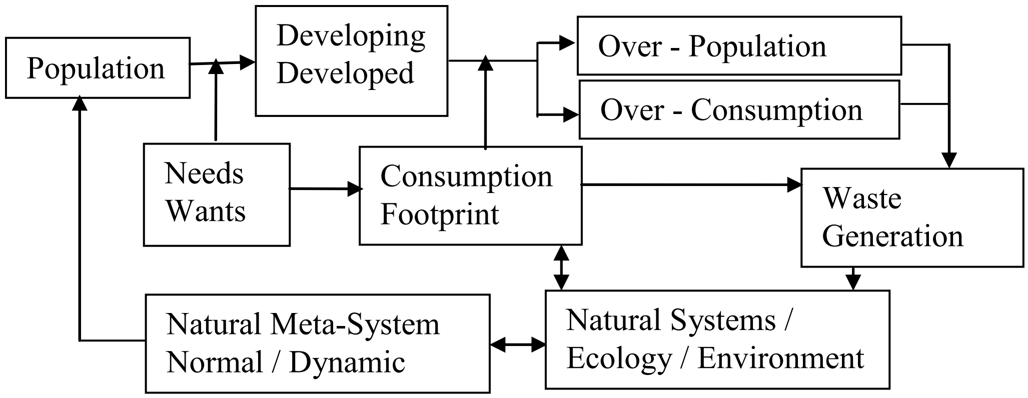


Fig. 2.8. Population, Consumption and Natural Meta-Systems

Needs and Wants in the Construction Industry are related to the scale and quality of the satisfiers in a given culture. A shelter achieves satisfaction of the need for <u>safety</u>, according to Maslow, and <u>protection and security</u> according to Max-Neef. Any further improving of the shelter condition, in the standards of living, etc becomes a want. Whereas needs are finite and can be readily satisfied with minimal resource consumption and thus considered sustainable, wants are open-ended both in number and resources (consumer overpopulation). Sheer number increase in populations, especially from the third world that transitions into a better quality of living is then achieving the satisfaction of a want.

Beyond the differentiation of needs and wants, there is another driver, greed, which is not part of the scope of this study. However, the reader may extrapolate wants to an insatiable degree to gain a concept of the magnitude and direction that this additional force can exert upon resources.

Needs, wants and greed are hereby treated in regards to the demographic shift of societies from developing and developed status, which impact resource consumption and waste/pollution generation. In particular, the demographic transition impacts the issue of shelter, one of the core human satisfiers of needs, as well as many of the other basic needs and wants which are satisfied around the household unit. In this regard, housing is tied both to basic population numbers as well as the move of populations from ‘developing’, to ‘developed’ and beyond. The global housing census taken from 1965 to 1974 on 60% of the inhabitants of the world left 1.6 billion inhabitants whose housing conditions are not reported in housing censuses, according to the U.N. Conference on Human Settlements, Item 10 of the Provisional Agenda as quoted by McHale (1978).

The U.N. document “World Housing Conditions and Estimated Housing Needs 1965” deemed at a minimum that the need would be approximately forty seven million new housing units per year for the foreseeable future (McHale 1978). These estimates were derived from the following categorized needs:

(a) Additional dwellings needed due to population growth.

(b) New dwellings to replace obsolete housing stock (calculated on the assumption that all buildings are to be replaced after 30 years)

(c) Additional dwelling require remedying existing shortages.

This document does not address the upper mobility of increased family size, changing locations, upscale drivers (more space, better quality) and others such as catastrophic events that destroy substantial building stock.

Concatenated with housing are the minimum living standards and considered the most critical dimensions of that standard are the needs for potable water[86] and sanitation services, which are beyond the scope of this study.

We have spent some time in investigating and analyzing needs and wants because not only they are major drivers identifying developing and developed societies but because the move from needs to wants is an innate force with humans that will resist any force that impinges on this progress. When theorist talk about reducing consumption there is a danger that what is implied is the reduction or elimination of accessibility to capital for developing societies. If this is not the case, we have little option than to grow, even though we meant no harm a la Seuss.

2.2.6 Preliminary Conclusions

The absence of consensus regarding the impact of global population growth and demographics in the area of building construction compels us to treat this area of research as in an early developmental stage and with heuristics. The criticality of the issues justify the use of heuristics to jump start the process. At this stage we have a continual competition between a number of distinct views of nature, population growth and demographics, each partially derived from and all roughly compatible with the dictates of scientific observations and methods. However there is an apparently arbitrary element (such as the estimates of population growth, the number of people per household, actual Total Fertility Rates, actual resource consumption in developing and developed countries per capita, the number of inhabitants moving from developing to developed status in a society, precision on the Ecological Footprint concept) compounded of

[86] Potable water is an identified threatened resource. However there is a discrepancy among scientist on the effect of global warming with some stating that more moisture in the atmosphere means more rain. On the long tern horizon is the relation of population numbers and water resources. If we settle with a 9 billion population or even a 6 billion population and we become accustomed at ever increasing use of water (again based on an increase in living standards worldwide) and the water resource is plentiful because of global warming, what happens when the CO^2 problem is resolved and the world returns to current lower levels of rainfall?

personal and historical accident, which according to Kuhn (1962) "is always a formative ingredient of the beliefs espoused by a scientific community at a given time." These are the soft data, the uncertainty elements, the 'messes' that need to be managed, the wicked problems that are in the swamp of this study, the swamp of important and real problems which require non-rigorous inquiry and a philosophical analysis before we can apply the tools of science.

History suggests that the road to a firm research consensus is extraordinarily arduous. In the absence of a paradigm[87] all of the facts that could possibly pertain to the development of a given science are likely to seem equally relevant. As a result, early fact-finding is far more a random activity (such as it may appear in this study) than the one that subsequent scientific development makes more familiar. Early fact-finding is usually restricted to the wealth of data that lie ready-to-hand. Pre-paradigm history is immensely circumstantial in detail, heuristic if you please, that later becomes sources of important illuminations.

The case study of China is critical, but it appears that other major countries, with similar population growth and demographics are following, such as India, and Mexico to a lesser extent. If the theory that 'technology uses all of reality, more or less distinctly, as resource to uncover a kind of energy that can, at will be independently stored and transmitted (distributed)', then the issue and challenge of finding those new sources of energy that are sustainable, clean and indefinite are real. However equally or even more critical is the issue of emissions generation. Meanwhile time is of the essence as population grows and moves into higher levels of consumption and waste generation, and there has been no logarithmic leap in construction on materials and processes that accompanies the logarithmic leaps of population and, more recently, demographic migration from developing to developed consumption.

This leads into the emissions and adverse environmental issues that are triggering a change in climate that will continue for several hundreds of years, if not thousands with right now unpredictable effects but nevertheless ominous in nature. Unfortunately, the issue of population, demographic, resource depletion, waste generation and ominous climate change will converge within this Century, hardly a legacy for the next generation. What that convergence will bring is relegated for further studies. Our next agenda is to enlarge the pre-paradigm messes, puzzles with the issues of population, demography, resource depletion and waste generation by re-defining the sustainability concept.

2.3 RE-DEFINITION OF THE SUSTAINABILITY CONCEPT

A simple analogy borrowed from Norton (2005) might be helpful to frame the issue of exponential population growth and exponential demands on resource and waste by significant demographic movements. Medical science use differential diagnostics (also known as Differential Etiology) like a formula that relates a person's height to body weight - easily measured quantities - to classify people as being of normal weight, underweight, overweight, or obese. Looked at from a scientific side, this index simply summarizes important descriptive information about an individual's height and weight, period. Medical practice however has a different interpretation though the technique of differential diagnostics. Given the current understanding of obesity in causing diseases (such as diabetics, heart attacks, etc) and the apparent undeniable connection of obese and overweight conditions to morbidity and mortality, the category 'obese' takes a host of evaluative and normative affirmations.

In this case, the index is a valued tool of communication in that (1) it provides a readily measurable, descriptive characteristic and in that (2) it provides a direct linkage to a host of

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[87] Kuhn's (1962) definition of a paradigm: "Universally recognized scientific achievements that for a time provide

individual and social values. The person can be measured and treated as a descriptive fact; given scientific knowledge about causal relationships and risk that allows the medical practitioner to predict that a person so classified has higher risk of illness and important recommendations can be given. A series of reinforcing 'values' from other disciplines such as Philosophy, Theology, Medicine and Law rounds up the reigning worldview, paradigm, mindset.

For example, Philosophy (science, technology, etc…) *the value of human life, pain can be induced as long as the intended and desired outcome is not death but life*; Theology, *the sacredness of human life*; Medicine *the Hippocratic Oath, prevent, treat and cure diseases, prolong life*; Law, *thou shall not harm or kill, etc*. The causality between height and weight thus play out within the social systems of systems.

In the case of population growth, a similar process, call it natural sustainability, is applied, albeit in reverse to our Differential Etiology. Nature has its own way of applying itself to population growth "sustainability" that up to recent functioned through the conditions that caused child-birth-death, mother-birth-death, pandemics, epidemics, deceases, plagues, famine, draughts, tornados, hurricanes, blizzards, etc… with impetus added by human social behaviour and practices of wars, slavery, genocide, etc that created a fertile ground for death, deceases, plagues etc, see *Fig. 2.9*.

These forces were a form of natural 'species' sustainability, in a pre-modern medical, technological, social, cultural, etc. intervention. In the cold sense, nature events take no sides, have no morality, extrinsic value or ethics (as we have seen in natural catastrophes) thus the population curve was relatively flat for thousands of years, except for the bubonic plague that

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model problems and solutions to a community of practitioners."

shows as a remarkable dip in an otherwise slightly slanted line; a dip that lasted approximately 400 years.

The t_c was what is now termed ‘geological time’ that is relatively slow time for doubling the species. Human interventions in the life-death cycle of humans, through Philosophy (science, technology etc), Theology, Medicine, Law and the exponentialoid proliferation of other specialized knowledge areas (Kuhn’s 1962), negated nature’s sustainability processes.

After this global human (counter nature’s sustainability) intervention, the population curve resumed the latent shape of an ‘exponentialoid’ a term coined in Spanish by García Bacca (1989) to depict the observable growth with multiple variable causes. With no sustainable or opposite force, the typical expected growth is exponentialoid, as attested by bacterial culture and other examples in his work (McHale 1972; Born 1969) that have no ‘restraining force’. Human intervention on ‘nature’s sustainable practice, due to a concerted and global set of human centric (anthropocentric) values and interventions, allows the exponentialoid curve to become manifested.

In other words, artificial sustainability[88] is the force that opposes an otherwise exponentialoid growth curve/force embedded in nature.

It is McHale’s restraining force. First, natural sustainability and negative human behaviour kept population growth in check. Human intervention in multiple, diverse and forcefully, starting circa the time of the Industrial Revolution and accelerated in the Modern times, allows population to grow unimpeded on its exponentialoid natural curve.

[88] García Bacca (1989) would define sustainability as refrained-infinite or infinite with finitude.

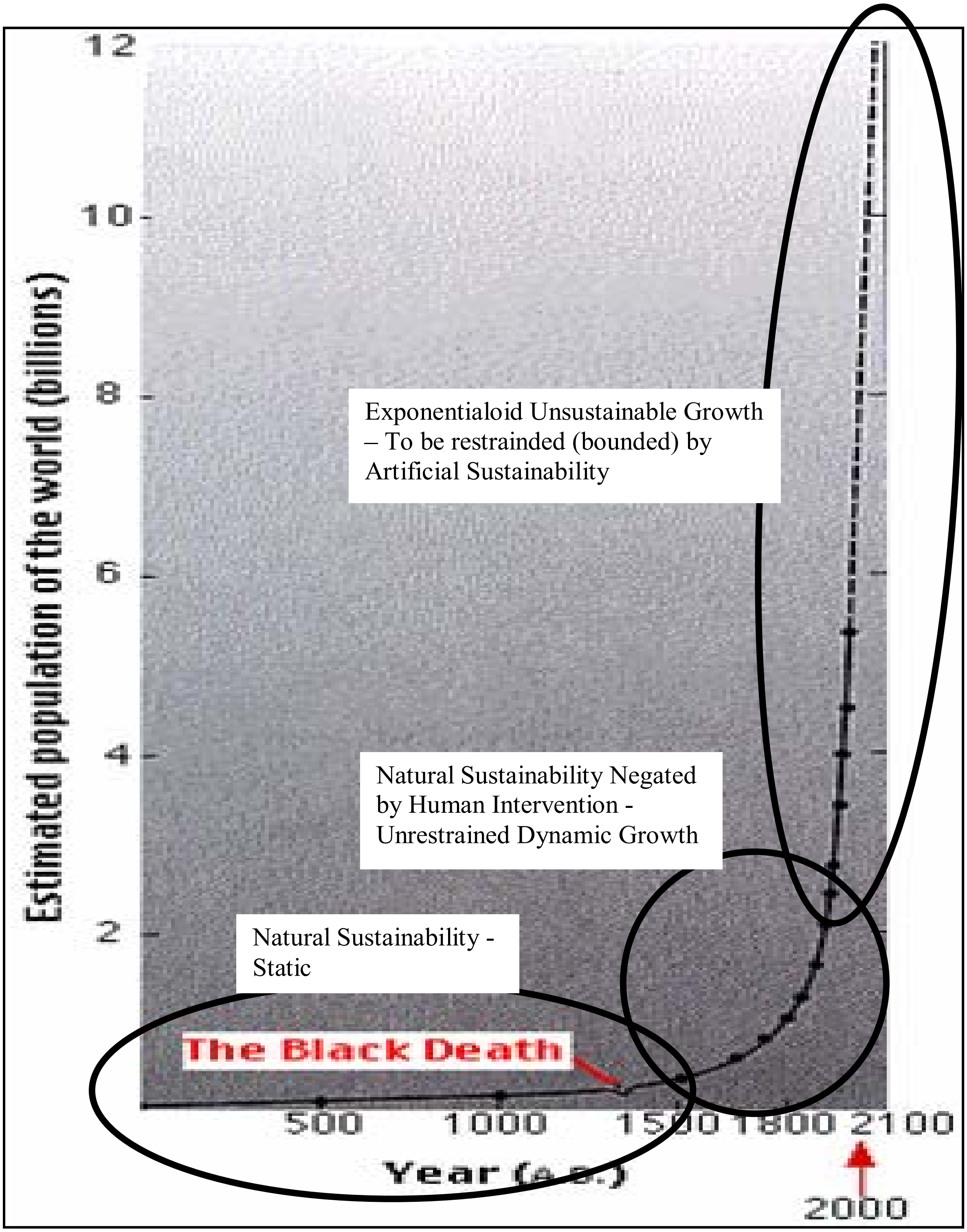

Fig. 2.9Relationship of Exponentialoid growth curve and the concept of sustainability

Artificial human intervention follows the population growth by attempting to tame the exponentialoid curve. Nevertheless, the concomitant growth in wealth, demographics, resource consumption, material depletion, waste and pollution generation are now exponentialoid as well and that is what sustainability aims to curb. According to McHale 1972, exponentialoids do not come isolated; others, not accounted in this dissertation, are subject for future discovery and study.

According to García Bacca (1989) Building construction, as well as all knowledge (and corroborated by Kuhn's (1962, 1976, 2000) observations, sciences and technological processes follow an exponentialoid growth curve[89]. Born (1969) stated that "the process of finding and applying knowledge, seen as the enterprise of the human raze throughout large time periods, has to follow the law of exponential growth and can not be detained." McHale (1972) asserts, "The exponentialoid does not grow isolated one from another, although that is how they are shown graphically." Based on these observations, we can examine the effects of population exponential growth, the exponentialoid nature of waste generation, resource depletion, building construction inventions, practices, processes and building construction capacity for change.

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[89] Another aspect of an exponentialoid can be gathered from Hawking (1998) work where the big bang exhibits exponentialoid characteristics that are 'inflationary,' meaning that the universe at one time expanded at an increasing rate rather than a decreasing rate. The first type is at the bottom of the "J" while the second type could be found at the top of an "S" curve. The rate of current exponentialoid such as emissions generation are expanding at an ever increasing rate thus is inflationary.

2.3.1 The Environment[90]/Sustainability Challenge

The relationships that exist between population growths, demographic demands on Natural resources and environmental degradation are complex (Raven and Berg, 2004). There are two population related drivers: First, in developing nations, the resources essential to individual survival needs are small (estimated at 20% of global resources and energy) but the large and rapidly increasing number of people (estimated at 80% of the global population) tend to overwhelm and deplete the non-renewable resources rapidly (overpopulation footprint)[91]. Secondly, in developing and highly developed nations, the relative numbers of population and population growth are relatively small in relation to the total global population (estimated at 20%) but have a higher standard of living, see *Fig. 2.10*.

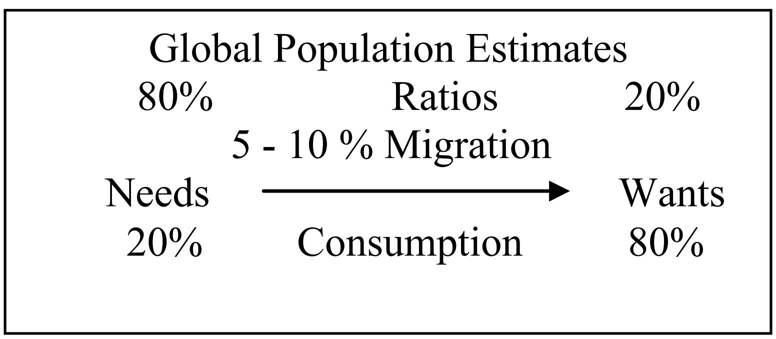

Fig. 2.10 Conceptual Model of Needs/Wants (Based on Raven & Berg 2004)

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[90] The interpretation of the word "environment" in this study is similar to the use by systems thinking where a system is nested in an environment and is separated by a boundary

[91] There are renewable and non-renewable resources. For example the Sun is the renewable resource that civilization until the last three hundred years has principally depended upon for survival. This study focuses on non-renewable resources, a one-time gift, which includes minerals and fossil-fuels (coal, oil and natural gas) that are present in limited supplies and are depleted by use (mostly by developed countries). Renewable resources (trees, fishes, fertile soil and fresh water) can be used forever as long as they are not overexploited in the short term (such as by developing populations that depend on these resources for daily needs and survival). In this case even renewable resources are termed as potentially renewable.

This higher standard of living carries a higher resource and energy consumption (estimated at 80% of the global resources and energy) producing an exponential depletion of resources with the accompanying degradation of the environment (over-consumption footprint). Furthermore, a recent event of large masses of population is rapidly transitioning from developing to developed state (estimated at an approximate annual shift of 5-10% of the global population) that further aggravates the resource consumption and environmental degradation curves, again over-consumption footprint (Raven and Berg, 2004; Venetoulis and Talberth 2005) see Table 2.5. An additional example of the magnitude of the current changes is: air conditioner production in China jumped 43% last year. China still has 250 million people without access to the national power grid. China added enough electrical and distribution capacity to generate energy of all of Great Britain (or Spain) in just one year (that is in 2004); The government plans on spending the equivalent of US $242 Billion to build 50,000 miles of highways in the next 30 years; China accounted for 31% of the world's increase in oil demand in 2004.

Table 2.5 Complexity of the Challenges. Adapted from Raven and Berg (2004

Population Growth Challenge

- Developing: **Large numbers** x basic needs
- Developed: Small numbers x **intensive consumption**
- Momentum: **Living Standard Growth**
- Displacement: Political, Economic, **Catastrophic Events**

Resource Consumption Challenge

- Energy: **Demand** / Depletion / Diversification
- Minerals: Demand / **Depletion** / Sustainability

Environmental Challenge

- Pollution: Adverse health potential
- Climate Change: **Catastrophic potential**

China highlights what happens when a model, such as the United States or European Union, scales up. Oil demand, for example is set to rise by 50% by 2030 (FT 10/20/06) as developing countries seek prosperity. The scenario is typical of all commodities: Major discoveries become rarer and demand keeps rising. In oil, the demand, at the going rate will be equivalent to 335m barrels of oil per day in 2030. An energy intense way of life or a high levels of prosperity and affluence, results in an ever-increasing consumption rate and demand. Claude Mandil, executive director of the International Energy Agency (IEA) states that: The world's energy economy is on a pathway that is plainly not sustainable." The statement is not new, but the outlook is worse than we had previously thought. This goes back to the exercise of estimating how much reserves exits, a highly heuristic exercise. Saudi Arabia, for example estimates to have 260b barrels of oil and the potential of another 200b. Exxon-Mobil now say that conventionally there are 3,200b barrels of oil and possibly another 4,000b barrels in difficult to access reserves. The 7,200b barrels represent approximately seven times the amount that has been consumed over the past 100 years. However, at the increasing rate of consumption all will be used in less than 50 years, if every real and imaginary barrel is found!

China economic and commodity demand increases (over 10% per year for the last four years) along with those of India (an economy growing at 8% and the rate is increasing FT 10/13/06) and later Mexico are significant and the potential for growth is enormous. Whatever paradigm is in vogue has to work from a modest early start up to an exponentialoid curve.

2.3.2 Resource Consumption, Sustainability and Technology

The United Nations forum on *"Our Common Future"* (The World Commission on Environment and Development, 1987) defines sustainability: "Today's needs should not compromise the ability of future generations to meet their needs". Pointedly, the Club of Rome publication "*The*

Meadows Report" (Meadows, 1972) observes that technological progress cannot be expected to ensure sustainability, including safeguarding resources and protecting the environment without some massive global initiatives that are not in the horizon.

> "*The argument that the world is running out of resources rests on two assumptions. One is that the reserves are not only finite which, of course, is a truism but that they are limited in the sense that resources can only sustain present rates of growth in consumption for a relatively short period of time. The second assumption is that the growth rate of consumption, if left to itself, is not able to respond to the reduction in that of supply. For even if prices rise sharply, the response to this through substitution or raw materials savings, would take too long to prevent ultimate depletion*." Perlman 1974.

Reserves estimation is hazardous since available estimates are generally revised upwards over time due to more extensive exploration and improved extraction techniques. For example,

> *"…reserves of copper have risen 3.5 times since 1935; of bauxite 7 times since 1950; metals and minerals available data suggest that, in many cases, these are ample for almost every material in the next fifty to a hundred years*." Varon 1975

McHale (1978) adds that the extension of reserves is not only a function of exploration and extraction technology, but also of use rates, functional resource competition, and substitution. At that time, the fear of projected inadequacy due to increased growth rates by major users (mostly USA, the USSR and Europe) seemed unfounded. "1978 population growth rates are declining in these countries and we have earlier shown that increased affluence alone is not necessarily paralleled by a consistent increase in materials' use." Such are the static characteristics of an exponentialoid in the constrained mode. However, at that time, the exponentialoid growth rate in affluence of a major segment of the global population, such as China, was not in the horizon. This demographical shift has unbounded the socio-political-economic sustainability restraints, allowed a system to become exponentialoid in growth by both population numbers as the latent basis and by affluence acquisition, the dynamic basis.

For example: Natural non-renewable resources: minerals[92] such as iron ore, copper, bauxite, selenium, alumina, zinc, ferro-molybdenum and fossil fuels, relatively unchanged for decades, that have doubled in price within the last two years. This price increase are unlike those seen in the 1972 temporary spike, the price increase appears to be permanent and the prices are across a number of different resources pointing to a recent exponential growth of construction activity. However, some economists contend that price is not a surrogate for demand and thus is not a reliable indicator of resource production and consumption.

Others argue that price stability is an indicator of resource stability. The argument that price stability indicates that natural resources, even though admitted to be exhaustible and un-reproducible, has been quoted by Baumol and Blackman (1993) as proof that innovation, recycling and waste reduction (Coventry and Guthrie 1999) has increased the productivity of natural resources by the same technological developments that have fueled the extraordinary growth in living standards since the industrial revolution. The argument states that these measures have increased the prospective contribution of the unused stock of the resources; thereby the stock of that resource is larger at the end of the year than at the beginning. Up to 1956 a group of researches (Barnett and Morse 1963 and Barnett 1979) found that the real price of extraction of thirteen minerals had declined, except lead and zinc, between 1870 and 1956. Unfortunately this author also quotes the stability of oil prices as indicators of resource stability.

The environmental-sustainability challenge deals with both of the following natural questions: (1) where do all the inputs in the form of raw materials and energy for production come from and (2) where do all the waste outputs go (McDonough 1992; Alarcón 1997; Stallworth 1997). The first question can be looked at in this way: Are we living out the interest on the endowment or have we begun to consume the endowment itself (Brown 1981)? Regarding the inputs, for example, the cement, lime, glass, paper, ferrous and non-ferrous metals, aluminum and steel 'industries' are major energy intensive construction resources. Regarding the outputs, for example, petrochemical products are prevalent throughout the construction industry, with buildings as the finished product, consuming 33% of the total global energy production (Energy Information Administration, Department of Energy, U.S. Gov.) and the cement industry is the worst emissions offender.

Warning voices from the 1900's have highlighted the case of un-restrained consumption of non-renewable natural resources, especially fossil fuels. Hickerson (1997) quotes biologist Ivie (1948) stating that "we cannot plan to operate for long on fossil fuel[93] as our major energy source. Instead, we must adopt a system of energy use (Schafer 2005) which will obtain a maximum amount of energy from renewable sources and a minimum amount from non renewable sources. – The Price System (General Economy) on the other hand refuses to face the problem, but seeks to deplete our limited fossil fuels (and mineral resources) at the maximum rate that will yield a "fair return in the way of profits." Even earlier, Scott (1933) wrote "the history of the human race may well be stated in terms of the ability of man to consume ever-increasing amounts of extraneous (non-human) energy. The limitation and stabilization of that rate of increase is the scientific problem of the not far distant future." This study adds to Scott's issue of energy the issues of conspicuous consumption of high-grade metallic ores and the need to find sustainable solution that will approach stabilization. However, these statements will elicit a Neo-Malthusian label.

Recently, several books have been published addressing the resource depletion concern, such as James Howard Kunstler 2005, *"The Long Emergency: Surviving the Converging Catastrophes of the Twenty-First Century,"* Paul Robert's 2005, *"The End of Oil: On the Edge of a Perilous New World,"* Richard Heinberg's 2005, *"The Party is Over,"* and David Goodstein's 2005, *"Out of Gas."* (See also Williams 2005).

During the last two hundred years, change is characterized by technical progress. Technical progress is composed of scientific discovery, invention, innovation (Pries and Janssen 1995; Slaughter 1991, 1993, 1998, 2000; Tatum 1996), improvements, and research (Seaden, 1996; Wortmann, 1992; Koskela 1992; 2000). This technical progress is part of the Industrial Revolution fuelled mainly by a fossil fuel based economy. However, according to the Olduvai Theory proposed by Duncan (1993) and 12 other experts including Bertrand Russell, J. W. Forrester, Donella Meadows, Richard Leaksy and others, the life expectancy of the Industrial Civilization predominant number as of 1993 was of one hundred (100) years. This placed a demise of the Industrial Civilization, based on fossil fuels at 2093, which coincides with the estimates of Hubbert (1982) of the year 2100. Although these projections have been subject of controversy (O'Neill and Desai 2005) and sometimes ridicule, we take a wait and see attitude. After all, the concept of light as corpuscles was also ridiculed as wave theory predominated only to be ascertained by Einstein latter on with the findings that it is particle (corpuscle) and wave, a paradox that not only applies to the micro and macro worlds but also to our real worlds.

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[93] Other industries will be adversely affected such as the Agriculture. Hickerson (1997) quotes Albert Bartlett of the University of Colorado stating that "Modern Agriculture is the use of land to convert petroleum into food." However, this subject is beyond the scope of this study.

Other voices, such as Baumol and Blackman 1993, propose that our exhaustible and un-reproducible natural resources, if measured in terms of their prospective contribution to human welfare, can actually increase year after year, perhaps never coming anywhere near exhaustion.

Table 2.6 World Reserves and Cumulative Production of Selected Minerals: 1950-1980
(millions of metric tons of metal content)

Mineral	**1950 Reserves**	**Production 1950-1980**	**1980 Reserves**
Aluminum	1,400	1,346	5,200
Copper	100	156	494
Iron	19,000	11,040	93,466
Lead	40	85	127

SOURCE: *Repetto 1987, p. 23.*

The answer to this proposition according to these authors is by viewing the effective stocks of natural resources as being expanded by the same technological developments that have fuelled the extraordinary growth in living standards since the industrial revolution, see Table 2.6. The argument is three-fold:

First, innovation has increased the productivity of natural resources (increase gasoline mileage of cars) or the reduction of lost minerals in the extraction or smelting (by using economies and techniques that decrease waste);

Second, through the (partial) substitutability within the economy of virtually all resources for others (even though at close analysis one mineral in scarcity is substituted by another on the way to scarcity);

Third, through recycling (such as in lead, iron, copper and aluminium) that also requires less energy in the process. These authors concluded, in 1993, “These three means can all increase the effective supplies of exhaustible resources and can augment the prospective economic contribution of the current inventory of resources, perhaps more than enough to offset the consumption of resources during the same period." Stumm and Davis 1991 show that recycling copper from chemical compounds and scattered materials, even in the case of infinite consumption of energy will only reach a share of about 70%. "Therefore recycling is not the solution of the shortage of stocks. Only with a not realistic recycling potential of 100% recycling could guarantee sustainability with not reproducible materials."

More recently, Baumol et al. (1989) calculated the price of fifteen minerals from 1900 to 1986 that until the energy crisis of 1970's had negligible upward trend in prices. However, 2004 has seen an increase in prices in Cement, Copper, Iron-Steel, Lead and Aluminium for diverse reasons that will be analyzed below. See *Fig. 2.12*. For example, The Wall Street Journal, Thursday, August 18, 2005 state that regarding mining companies, "on Tuesday, copper hit a new high on the London Metal Exchange of more than $3,600 a ton. Nickel, though down a bit from two months ago is selling for about three times its 2001 price. A widely followed measure, the Reuters Jefferies CRB Index, which tracks a broad range of commodities, is more than 50% higher than it was four years ago".

Carassus 2004 international work regarding a worldview of the construction industry as a construction sector system (at the mesoecomonic[94] level) provides the logic for a counter argument: It appears that developed economies, in regards to construction in general and building construction in particular, do reach a level when capital assets development slows down while management of existing facilities increases. However, the vast number of the global population is underdeveloped and thus a long horizon increasing demand for construction.

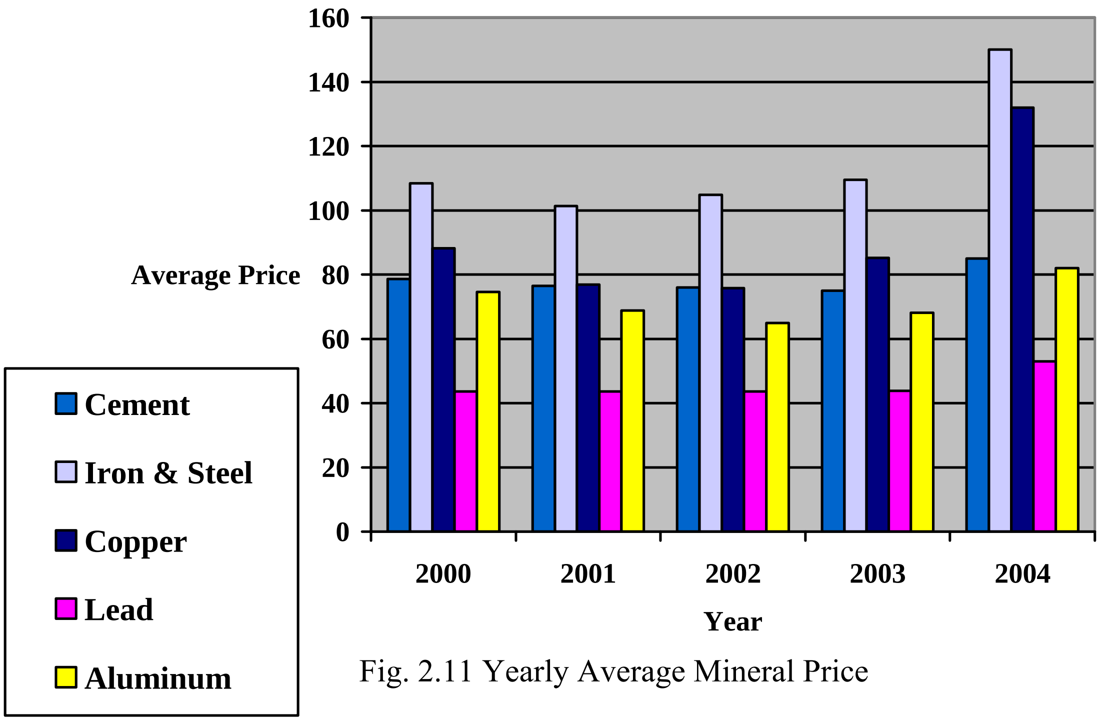

Fig. 2.11 Yearly Average Mineral Price

Again, China and India increased demand for these commodities is also mentioned. Four years does not constitute a trend, however the query, as posed in this dissertation, is whether we continue to be in a sustainable portion of a growth curve where the slope is moderate or are we at a point where forces of demographics have unleashed the growth into an exponentialoid. We now investigate in detail some of the basic commodities used regularly in building construction regarding recent trends.

2.3.2.1 Cement:

In the U.S., a strong residential construction spurred by very low interest rates offset stagnant private non-residential construction. Cement companies were not able to build clinker stockpiles ahead of kiln maintenance shutdowns and instead delayed shutdowns in expectations of a

[94] 'Meso" is a Greek word denoting the state between the Micro and the Macro levels (Holland 1987 cited in

relaxation in cement demand that never came. US cement production in 2004 of 96.5 Million metric tons (Mmt) was up from 2003 of 94.3 Mmt (2.2 Mmt) and compares to China's 2004 of 850.0 Mmt up from 2003 of 813 Mmt (37 Mmt). 98% of cement is used in one form or another for construction. FT 2006 reports that China in 2005 consumed 42% of all the cement consumed in the world.

World Resources: According to USGS, although individual companies' reserves are subject to exhaustion, cement raw materials, especially limestone, are geologically widespread and abundant.

Substitutes: Concrete is substituted by aluminium, asphalt, clay brick, rammed earth, fibreglass, glass, steel, stone and wood. Pozzolans and similar materials such as fly ash and ground granulated blast furnace slag, are increasingly being used as partial substitutes for Portland cement in some applications.

2.3.2.2 Iron-Steel:

Construction uses approximately 14% of the US iron-steel production. Recycled iron and steel scrap is a vital raw material for the production of new steel and cast iron products. The US has recycled steel scraps for more than 200 years and the automotive industry alone recycled about 14 million vehicles in 2004. The recycling rates for construction steel scraps are expected to increase in the US and emerging industrial countries such as China. Scrap prices increased substantially form $108 in 2003 to $190 in 2004. According to the USGS "the tremendous increase in iron ore consumption in China in 2003 of 261 Mmt to 2004 280 Mmt (19Mmt) compares to the US 2003 of 46 Mmt and 2004 of 54Mmt (8Mmt) affected the US iron ore production for the first time in history. A major Chinese steel company purchased minority

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Carassus 2004).

interest in a bankrupt iron ore producer in Minnesota and accepted for their portion of the production from the majority partner's Canadian affiliate." China has become the dominant source of iron ore demand growth. In 1992 China surpassed Japan as the leader in producing pig iron (98% of ore iron and thus a good indicator) at 76 Mmt and in 2003 it produced 200 Mmt and continues to grow at a 9% rate per annum since 1992. "China's astonishing growth affected the large global iron ore producers in Brazil and Australia who continue to invest large sums of money to increase production to satisfy Chinese demand (an estimated 33% increase from the 2004 global production is expected from these two sources by 2009). China is in 2004 the worlds largest producer and consumer of steel. China's production increased form 272 M tones in 2003 to 336 M tones in 2004 (approximately 25%). In 2004 China had to import 13 M tones but this situation is likely to change with its over-production. The overcapacity (2- - 30 M tones in 2005 and possible 50 M tones in 2006) in the world's largest producer and consumer of steel could damage world price stability.

World resources: Crude iron ore world resources are estimated to exceed 800 Billion metric tons (Bmt) containing more than 230 Bmt, however total global mine production in 2004 was of 1.25 Bmt.

Substitutes: Iron is the least expensive (to date) and most widely used metal and competes with lighter materials such as aluminum and plastics in motor vehicles; aluminum, concrete and wood in construction and aluminum, glass, paper and plastics in containers.

2.3.2.3 Copper:

Eighteen percent of Copper and copper alloys are used in construction. Old scraps provide 225,000 metric tons of copper or 9% of apparent consumption in the US of 1.16 Mmt. World mine production of copper rose by .9 Mmt or 6.6% in 2004 but there was a .375 Mmt deficit in

2003 that grew to .7 Mmt in 2004 from demand outstripping supply. Copper use in China in 1995 was 1.19 Mmt by 2005 it more than trebled to 3.61 Mmt it now accounts for 22% of the global demands. In 2003 China surpassed the US to become the world's largest consumer of copper and by 2004 it consumed 46% more than the US in the areas of construction, power generation and electricity networks.

Global inventories continue to decline and prices have doubled from 2005 to 2006, that is, in one year. The FT10/13/06 reports that "strategic inventories of refined copper are expected to be depleted by the end of 2007 with little opportunity for rebuilding before the next global recession." The reason for this depletion is a combination of weal mine production and increased global demand. Strikes in La Caridad and Cananea in Mexico and Escondida in Chile conspired to have a year production of 14.87m tones from 15.22m tones in the previous year. The forecast for 2007 is now at 15.86 when it should have been 16.16m tones. The deficit in 2006 is of 300,000 tones and in 2007 expected to be at 100,000 tones with a tiny surplus in 2008.

The electrification of China's rural areas, the countryside (of more than 400M people in conservative estimates, roughly double the US population) is just getting started, reports Geoff Dyer of the FT, May, 2006. China in this report is adding 60,000MW of new generation capacity each year until 2010; this is the equivalent of adding more than Spain's entire energy system each year. China expressed capacity need at this time is of 750,000 MW and they reached 500,000 MW. India, with an equally large population, is lagging behind its needs so there is another potential for continual growth in this commodity. Western European copper consumption is also increasing at a rate of 9.5% instead of the previously estimated 7.5% (FT 10/13/06).

World resources: A recent assessment indicates 550 Mmt of copper but land based resources are expected to be much higher at 1.6 Bmt with an additional .7 Bmt in deep sea nodules, however total global mine production in 2004 was 14.5 Mmt.

Substitutes: Aluminum substitutes for copper in various products. In some applications titanium and steel are copper substitutes and optical fiber in telecommunications. Plastic is a substitute in water pipes and plumbing fixtures.

2.3.2.4 Lead:

Lead use in construction is decreasing in the US. Its primary use is in batteries. Approximately 1.14 Mmt of lead is recovered in the US annually. Lead prices increased in 2004 by 20% in the US and 66% in world markets. According to the USGS the "main driver for this growth was higher use in China for vehicle fleet expansion, telecommunications and information technology." Despite a 6% increase in global mine production, refined lead production was stagnant in 2004, thus a significant production deficit for refined lead was experienced in 2004 and is forecasted to continue in 2005.

World resources: Lead resources are estimated at 1.5 Bmt and mine production in 2004 was of 3.15 Mmt.

Substitutes: Plastics has reduced the use of lead in building construction (and water in paints) electrical cable covering, cans and containers. Tin has replaced lead in solder for new potable water systems in the US.

2.3.2.5 Aluminum:

US Aluminum consumption is 30% for transportation (airplanes, and all types of ground transportation), 13% in buildings and 6% in electrical. Recovered aluminum in 2004 was 3 Mmt which is 19% of apparent consumption. Canada, Mexico and China received more than 80% of total US exports. World production continues to increase.

World reserve: The world reserve for bauxite is estimated at 75 Bmt while mine production was 156 Mmt. However, USGS estimates that there is essentially an inexhaustible sub-economic resource of aluminum in materials other than bauxite such as clays, anorthosite, alunite, coal wastes and oil shales.

Substitutes: Copper can replace aluminum in electrical applications; magnesium, titanium and steel can substitute aluminum in structural and ground transportation.

2.3.3 Example of Theoretical Scenarios

For discussion purposes and to find an edge to the envelope, we assume that current mineral reserves in Iron ore, Copper, Lead and Aluminum, in this hypothetical scenario, are:

- Fixed with current estimates (that is no new significant discoveries, a highly unlikely scenario)
- There is a moderate increase in the global recycling of some minerals (a likely scenario) and
- There is a 10% yearly increase in global demand (translated in mining demand, also a likely scenario)

The question posed, on this speculative problem is: when will the current amount of resources be depleted? The scenario may be construed as the worst case scenario, with the understanding that the best case may add additional decades to the results. All estimates are taken from the US Geological Survey (USGS) 2004 data. In greater detail, the problem was posed to the Students in Paris 2005 SAP[95] as follows:

Iron-steel

a. Crude iron ore world resources are estimated to exceed 800 Billion metric tons (Bmt) containing more than 230 Bmt of iron, and
b. The total global mine production in 2004 was of 1.25 Bmt.
c. If world consumption of iron (global mine production) increases 10% each year, how many years will it take to deplete current estimates of crude iron? See *Fig. 2.12*.

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[95] Some of the students participating in the program that contributed to this analysis are: Thomas Callahan BC05, Michael Delashmit BC07, Rachel Heim BC06, Brett Haynie BC07, Jason Kiefer BC06, Erin Looney BC06, Greg Munna BC06, Ashley Ryan BC06, Viktoria Sazonova BC06, Jacquelyn Schneider BC06

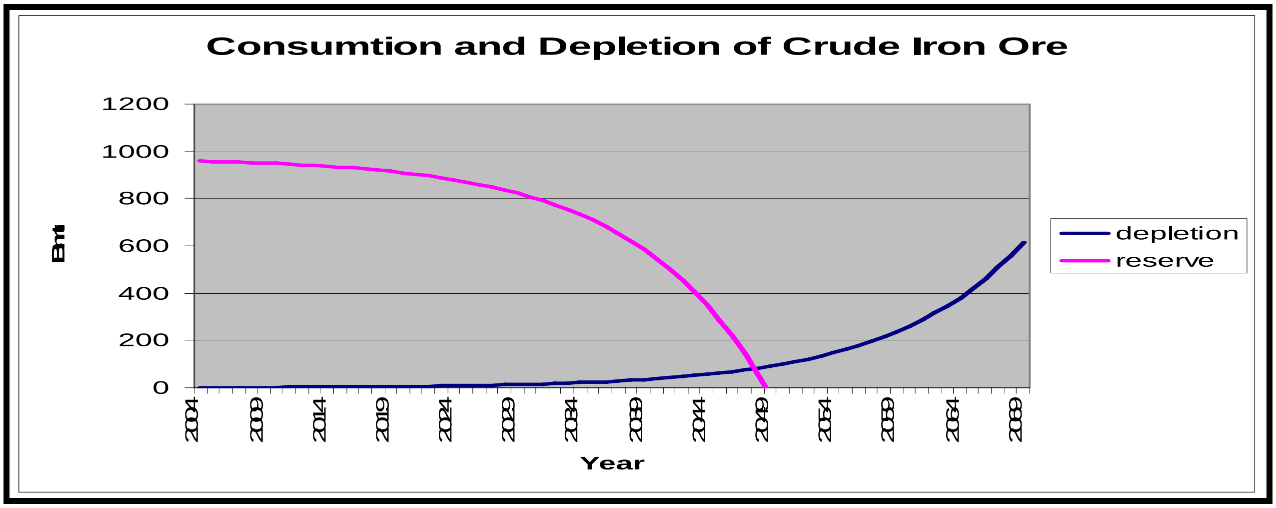

Fig. 2.12 Consumption and Depletion of Crude Iron Ore

Copper

a. A recent assessment indicates 550 Million metric tons (Mmt) of copper but land based resources are expected to be much higher at 1.6 Bmt with an additional 0.7 Bmt in deep sea nodules, recycling of copper at this time is estimated to be negligible.
b. However total global mine production in 2004 was 14.5 Mmt.
c. If world consumption of copper (global mine production) increases 10% each year, how many years will it take to deplete current estimates of all land and sea based copper? See *Fig. 2.13*.

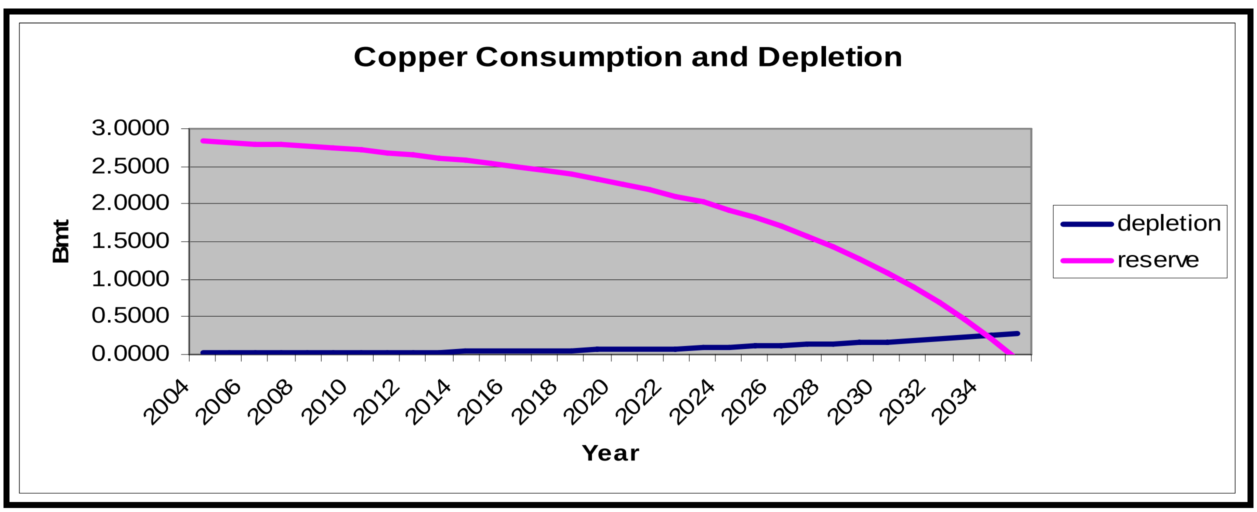

Fig. 2.13Consumption and Depletion of Copper

In the case of copper, several factors are reported to account for the present condition: The cost of improving and adding resources to increase production; The increase cost of energy; The need for large quantities of water to treat the mineral; That current mining deposits have a smaller yield and thus not as profitable; Social (demand for more wages and fewer hands for employment) and governmental (taxes or even confiscation of natural resources) issues: Economic strategy to reduce production to keep prices high; The fact that copper and molybdenum are found together and right now molybdenum, needed for the stainless steel industry, commands higher market prices and thus more profitable (shifting mining resources towards this commodity.) All this have created a situation where demand is greater than supply and will be for the foreseeable future, especially with demand increasing and absorbing any new productivity. (FT special editions on copper 5/10/2006 & 5/26/2006).

Lead

a. Lead resources are estimated at 1.5 Bmt and
b. Mine production in 2004 was of 3.15 Mmt.
c. Approximately 1.14 Mmt of lead is recovered in the US annually (automobile batteries)
d. If world consumption of lead (global mine production) increases 10% each year, and the amount of recovered lead each year increases by 5%, how many years will it take to deplete current estimates of lead? See *Fig. 2.14.*

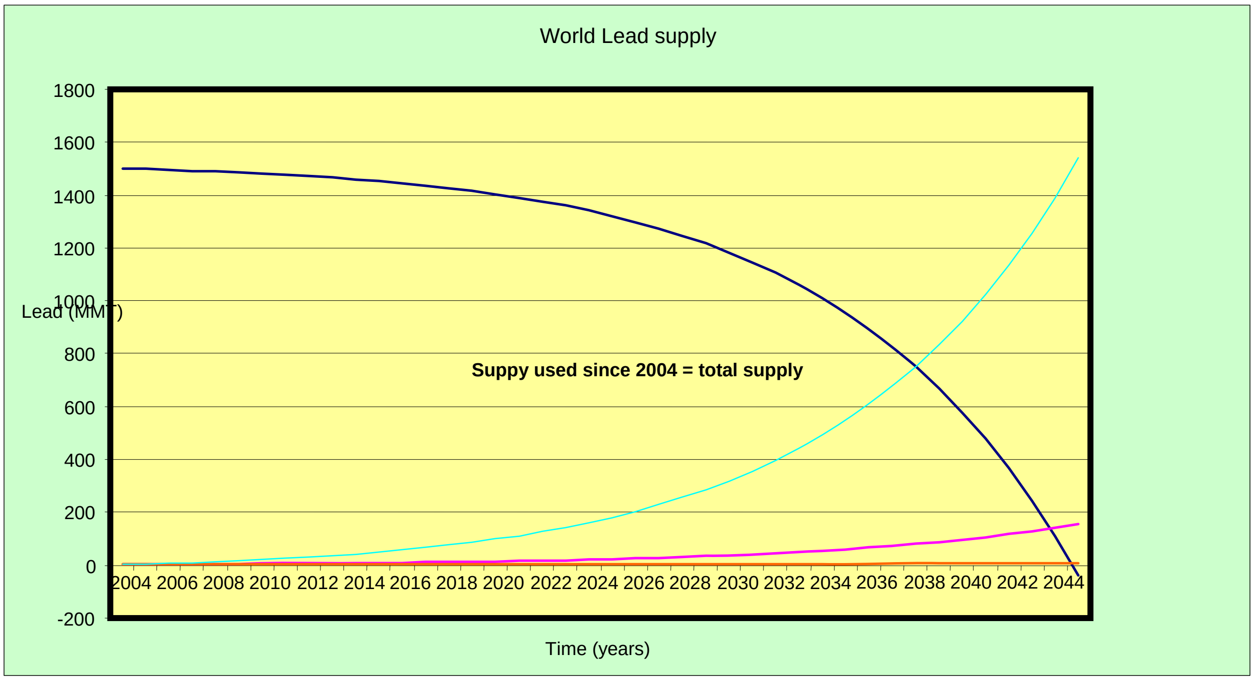

Fig. 2.14 Consumption and Depletion of Lead

Aluminum

a. The world reserve for bauxite is estimated at 75 Bmt while mine production was 156 Mmt. Other sources of aluminum such as clays are prohibitive at the present time.
b. Recovered aluminum in 2004 was 3 Mmt which is 19% of apparent consumption.
c. If world consumption of aluminum (global mine production) increases 10% each year, and the amount of recovered aluminum each year increases by 5%, how many years will it take to deplete current estimates of aluminum? See *Fig. 2.15*.

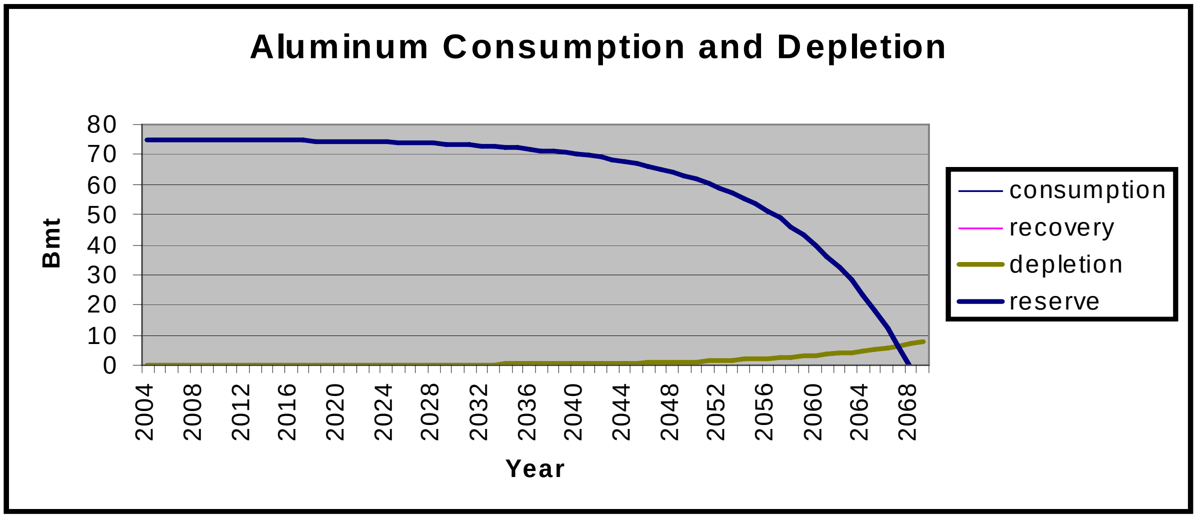

Fig. 2.15 Consumption and Depletion of Aluminum

On the other hand, experts claimed in 1999 that these resources can not be physically depleted, (ST/ESA/1999/DP. 5 DESA Discussion Paper No. 5, Trends in Consumption and Production: Selected Minerals Prepared by Oleg Dzioubinski, Ralph Chipman, March 1999, United Nations.)

The question of resource depletion is one of the hottest topics among economists who discuss resource issues and sustainable use of them. As previously mentioned, most economists are not accepting the concept that resources are finite and can be depleted. According to Norton (2005), "there have been celebrated studies that show there are no downward trends in the percentage of prices devoted to natural resource inputs. This goes back to the famous 100-year study of commodity prices by Barnett and Morse 1963. They found that, in most cases, the percentage of retail commodity prices devoted to resource inputs fell significantly. Follow-up studies in top econ journals have tended to support this, and there is the famous bet where Julian Simon destroyed Paul Ehrlich 1969 in the famous wager. If current trends of resource depletion go exponential, prices would be headed for higher and higher. It looks like the dissertation has to show that trends that are 150 years old will have to reverse and then grow at an exponential rate."

Precisely, unexpected and inordinate price increases in commodities related to construction have taken place in the last couple of years, although we acknowledge that this is not considered a 'trend.' See Table 2.7. The predictability, based on economic historical trends, form the core issues. Can we look to the past to predict the future? (FT 10/17/06 has lead up to $1549; nickel at $33640; tin at $10095 and zinc at $3880).

Commodities Price Increases	**Table 2.7**					
	FT 10/9/05	**Ft 10/9/04**	**FT 9/28/06**	**05/06**		
Commodities	**High**	**10/9/04**	**High**	**Price increase**	**High/yr ago %**	**High/ 2 Yrs ago %**
Aluminum HG	2031	1664	2501	470	**23.1**	**50.3**
Copper GR A	4356	2841	7706	3350	**76.9**	**171.3**
Lead	1011	926	1400	389	**38.5**	**51.2**
Nickel	28725	12278	31150	2425	8.5	**153.7**
Tin	10088	8952	9205	-883	-8.8	2.8
Zinc SGH	7705	955	3419	-4286	-55.6	**258.0**

However, Philosophers of technology and invention agree with García Bacca (1989) that no invention of the past is a predictor of the next, directly or indirectly. Each invention stands alone in coming out although may be based on previous models. If this is the case then it could be interpreted that the economy may be moving into a new mode that is not anticipated by previous trends, just like technology and inventions are no predictors of future technology and inventions. According to McHale (1978) all these, technology, inventions, economy, etc move exponentialoid, do not move in isolation, and are not deterministic one of the other.

The economic issues are not resolved and are hotly debated. Kuhn's (1976) dictum applies here, "nothing about the rationality of the outcome of the current evaluation depends upon their, in fact, being true or false. They are simply in place, part of the historical situation within which this evaluation is made." Thus for the last 150 years prices have receded. Right now they are increasing and some are becoming dynamic and even increasing exponentially. Kuhn (2000) adds the proverb: "As in individual development, so in the scientific group, maturity comes most surely to those who know how to wait."

2.3.4 Other Observations

New technologies in finding resources, mining, recycling and innovations in the use of these resources may extend the effective life of mineral deposits, but current indication is that the rate of consumption off all the minerals as well as fossil fuels is currently relatively flat at the bottom of the "J" curve with demand rising exponentially. This consideration will have major economic, social and political implications to the countries where these natural resources reside as well as to the economies consuming the resources. Furthermore, the theory of substitutions, unless new materials are created, appears to lose strength when all (including current substitutions) are experiencing the same pressures in consumption and depletion. This raises the possibility of a scenario where most resources approach extinction within a relatively short period of time, all within that same period of time.

Next, we will address the ecological and climate change impact from the use of these resources and the energy required to transform them into products, especially in the building construction industry.

2.3.5 The Environment and Climate Change

Global warming is a reality surrounded by theory. The measurement and analysis of the global warming rate is a source of controversy. Other metrics, such as the global carbon emissions from fossil fuel burning, which is the chief suspect of global-warming gases (see *Fig. 2.16*), has greater acceptance among scientists like the Scripps Institution of Oceanography, the Lawrence Livermore National Laboratory, and the American Association for the Advancement of Sciences.

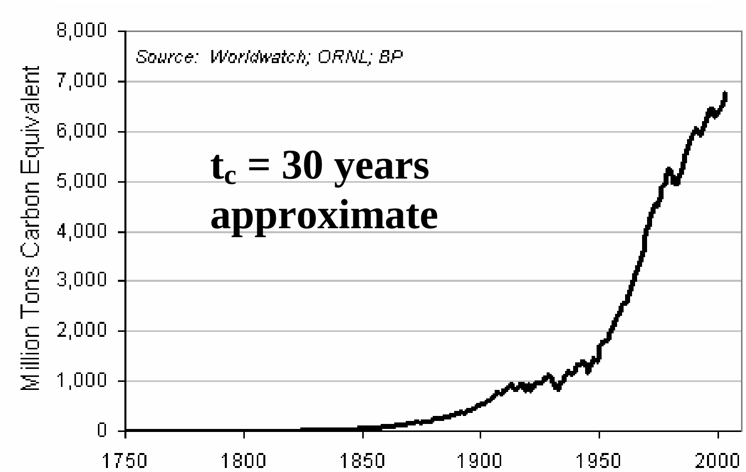

Fig. 2.16 Global Carbon Emissions from Fossil Fuel Burning 1751-2003

The input and output challenges raises the question of whether the building construction industry has the capacity for change while in the process of creating capital projects. At the same time, the final product consumption characteristics, which are sufficient in scope and magnitude to meet current and future challenges, must be considered. The second rule is that population and related building growth exacerbate both the depletion of natural resources (inputs) and the environmental degradation (outputs), which leads us to the challenges of productivity and processes.

Global warming and its possible catastrophic consequences is a complex 'mess' that for the purposes of this study is simplified in how it may affect population growth and how it may affect building construction. Regarding population growth, catastrophic events stemming from global warming caused by human activity is a density dependent factor in a paradoxical way: Certain environmental factors, according to Raven and Berg (2004) have a greater influence on a population when its density is greater. For example, if a change in population (such as rapid doubling of population) density alters how an environmental factor affects the population (CO_2 gas emission), then the environmental factor is said to be a density-dependent factor[96]. At the same time, climate change and catastrophic events could adversely affect the size of a population and in this case is called a density-independent factor which is indirectly influenced by changes in the population (such as the aforementioned rapid doubling of population).

How significant is this issue? The above graph issued in 2003 showed that carbon emissions were estimated at 6.8 Billion tons of carbon equivalent with the calculated t_c of 30 years. The predicted 2005 the carbon equivalent jumped to approximately 28 Billion (or Giga) tons making the t_c of 1 year. The causes for this jump are subject of speculation at this time but the major changes in standard of living and demand increases that could affect changes in this magnitude are in Asia and India. McHale (1978) stated: "Many have projected that increased energy and materials use will not only lead to critical scarcities but also have dire consequences for the environment, this, they say, will retard the development of the poorer countries. However, even if these developing countries increase their use of the world's resources by 50% of their present 10% share, over the next twenty years, their share would still be only 15% of total world resource use" (Varon and Takenchi 1974). At the time of these statements, again, the rate of increase and t_c at the bottom of the exponentialoid appeared sustainable and tamable. History as we know it is proving, as we speak, what happens when the rate of growth accelerates in a milieu that has a very large population base and the capacity for consumption is unleashed.

2.4 THE PRODUCTIVITY/PROCESS TECHNOLOGICAL CHALLENGE

Within the last twenty years, the construction industry has undertaken numerous initiatives to identify and improve productivity and processes (Nightingale 2000). The drivers for these initiatives have been, generally, cost reduction[97], schedule compression or quality improvement, in combination, stand alone or prioritized in relation to the process, services and or final product.

Productivity in building construction may be high on constituent processes that are of a repetitive nature, however overall construction has a low productivity, and low quality (Butler 2002) in comparison with other industries because of diversification and design uniqueness. Productivity, according to Espinas (quoted by Mitcham 1994) is based on techniques, technologies and Technologies. Techniques refer to some skills of some particular activity, 'technology' (lower case as the systematic organization of some technique), and Technology

[96] A density-dependent factor must affect a large proportion of the population, not just a larger number of the population. Density dependent factors eventually will tend to regulate a population.

(generalized principles of action that would apply in many cases). The ideas of Espinas and the Polish philosopher Kotarbinski (1965) blends into what are now called systems theory, game theory, cybernetics, operational research, and various theories of management that along with reflections from Jacques Lafitte (1932) and Gilbert Simondon (1958) (as quoted in Mitcham 1994) distinguished the phenomenology (Embree 1996) of technological evolution in elements (parts), individuals (wholes) and ensembles (systems).

The process of construction has profited from the following trends and initiatives, among others (see Appendix J, Part II):

- **Organization related:** Project Management; Partnering; Project Definition Rating Index, (PDRI™); Learning Organizations; Knowledge Management
- **Performance related:** Total Building Commissioning; Lean Construction; Concurrent Engineering and Fast Tracking (Ranky 1994)**;** Just in Time Production (JIT)**;** Total Quality Management**;** Continuous Improvement Theories**;** Theories of Integration**;** Robotics; Constructability and Buildability; Value Engineering/ Management; Life Cycle Costing; Critical Path Scheduling
- **IT related:** ^{n}D CAD - parametric oriented, web based real time multi-user platforms, Digital Building Process and As-built Documents
- **Codes and Standards related:** Performance Base Building Codes, Standards and Specifications.
- **Fees and Structure related:** Integrated Project Delivery Systems (such as: Design-Build, Construction Management @ Risk and multiple variations); Subcontractors and Vendors Alliances.
- **Environmentally related:** LEED®; BREEAM™**;** GBTool™ (UK); BASIX (Australian); HQE^{2}R (CSTB - France)
- **Facilities Management:** Energy Star™**;** Benchmarking, Continual Commissioning

As previously mentioned, it is highly suspected that these initiatives were initiated by the industry response to local problems and issues and therefore affecting differing aspects of the industry with varying degrees of effectiveness. The expected increase in efficiency (Emerson 1917), productivity, cost controls, and schedule compression, combined with the anticipated decrease in litigation (DiDonato, 1993) and conflict from all these initiatives, await performance

[97] Cost reduction takes many forms, some of which are: increasing productivity of labor, new products, and energy

(Tang and Ogunlana, 2003) studies and data verification. The construction industry is also characterized as being fragmented (Gann, 1996, Pike 2002), and even backwards (Woudhuysen and Abley 2004), with individual corporate players implementing the above-mentioned initiatives at a varying number and to different degrees. Each of these initiatives adds a level of complexity to the practice and requires a focused integration into existing organizational structures and systems.

However, lessons learned are not irreversible (Egbu, 2004; Fox et al. 2002) and require re-application if not re-discovery for every project's differing team. Differentiating building construction from pure manufacturing is Koskela's (2000) observation that construction is on site, one of a kind, and done by a varying team of players[98] (also see Riis et al. 1992). The number of environmentally sensitive projects is increasing exponentially, while at the same time, the total number of LEED projects (1,800 approximately), in relation to total number of construction projects (hundred of thousand annually) is miniscule (see Table 2.8).

Table 2.8 Growth in LEED Implementation (www.usgb.org)

Cumulative Totals	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006** (June)
LEED Registered	16	132	266	419	786	1363	406
LEED Certified	12	5	21	46	119	199	54
M. Sq. Ft.	5.7	18	35	65	115.5	214.9	64.4

efficiency through reduced weight and/or thickness, etc. (Turner, 1986).

[98] These variability parallels Jose Ortega y Gasset (1939) observation that human life entails a relationship with circumstances as an active response to and creator of the circumstances that includes: 1) creative imagination of a project or attitude towards the world the person desires to realize and 2) the material realization of the project, involving certain technical requirements for its realization. By this interpretation of nature, humans have to 'choose, to select' between fantastic possibilities, and in choosing change is generated. The relational flow is: intelligence – un-satisfaction – change desire – create – change realized. The act of creation consists of setting up and challenging Nature to yield a kind of energy that can be independently stored and transmitted at will.

The presence of these trends and initiatives are a testimony to building construction's innate capacity for change. Change has historically come through differing ways: chance (where no method of discovery is present); through techniques (conscious change process that are passed from one generation to another by a special class of artisan or craftsmen); and through the application of the principles of modern science (with an analytical way of thinking and application of scientific techniques). In the words of Ortega y Gasset (1939), "people know how to realize any project they may choose even before they choose some particular project." Ortega y Gasset observes that current modern techniques for achieving change may be "drying up aboriginal faculty that accounts for the invention of human ideals by loosing the ability to will any ends at all."

The macro issue regarding these initiatives is the question of whether these trends and initiatives, or their synergy, are tapping sufficiently into the building industry's capacity to change in order to substantially meet the current and future challenges, considering the gap between academia and practice. For instance, Davis Childs was the project architect for Skidmore, Owings and Merrill (SOM) Architects on the construction of the Worldwide Plaza in NYC, 1986-1989. Sabbagh (1990) quotes Childs stating, "Knowledge of textbook management procedures, architectural design skills, engineering measurement, and logistical flow charts are as useful as an Italian cookbook when faced with the realities of building a high-rise building in New York in 1987. What is useful there are nerves of iron, ability to hope for one thing and expect the opposite, a degree of street level profanity, and an unflagging sense of when to tolerate the intolerable. A building is a one-shot creation nearly everything is being done for the first time, apart from basic tasks."

The search for one best solution, efficiency, and optimization to technical problems can yield superficially different results, but according to Ellul (1954) this in no way undermines the comprehensiveness of the technical phenomenon. Sustainability is the force intended to curb or restrain the exponentialoid growth in population, consumption, use, waste generation, pollution, use of resources etc. Sustainability has two major definitions in this scenario: Sustainability defined regarding re-generative products and sustainability defined regarding products that can not be re-generated. Economists argue that scarcity drive prices up, spurs alternative solutions and makes current supplies last much longer than predicted. Unfortunately, USGS show that the alternate for all the minerals considered are either other minerals in the same depletion mode or synthetics derived from fossil fuels that are also part of the exponentialoid depletion curve. That leaves us with the task of firstly, creating not only new energy sources that are not related to fossil fuels and secondly finding new minerals in large enough quantity that can not be depleted (highly unlikely) or finding processes to use the existing stock that is exponentially more efficient than current methods and systems.

The first item, new sources of energy, is not part of this dissertation but the following observation is made: Whatever new source replaces the diminishing resources must catch up with the exponentialoid increase in demand and be of such nature that it not only catches up but has the potential of being inexhaustible. According to philosophers in technology, the magnitude and type of such new technology has the tendency of making existing technology and processes of production and use obsolete. Technology, for instance, has yet to make fossil fuel energy, as a source, obsolete. This is a radically different concept from that of technology prolonging fossil fuel energy source, a view that although insinuates hope in technology, actually may also be viewed as a lack of hope in radical technology that once and for all displaces sources that are constrained by limitations.

The second item, finding processes to use existing stock that is exponentially more efficient than current methods. That is, using quantum less material and energy in extraction, transformation and assembly through a quantum leap in using the material characteristics and attributes, thus guaranteeing that for the long-term, resources appear to be inexhaustible will also render current technologies (IISD, 2005b) of extraction, production and use obsolete.

2.5 CONCLUSIONS

In this chapter We have addressed the issue of building challenges: population numbers (how population numbers have increased in a historical time line), demographics (change from developing to developed status by large segments of the population), a case study of China (example of the number and demographic change affecting both resources and emissions), and the underlying reasons for those changes (the universal human, social and cultural drive from needs to wants). The purpose is to set the stage for creating a worldview, a schema of the problems and therefore a first step towards gathering the heuristic information for a better understanding of the nature and even more the magnitude of the problems. We focused on the question of exponential growth, first in population and secondly on population dynamics (demographics) to understand the growth dynamics that telescopes into all other areas, specifically building construction's rate of resource consumption and emissions generation. We are confronted with a 'pincer', dual problem: Resources on the input and Emissions on the output with strong links to population and wants.

What we found on population growth time line is nature's sustainability or better yet human intervention that unleashed an exponentialoid hidden in nature's sustainability. In other words, nature had its own way of defining 'sustainability' – a balance between resources and conditions and population that has been relatively steady for thousands of years, based on pandemics, draught, weather related disasters, etc…which human benevolent intervention (towards the human race specifically!) negated unleashing an exponentialoid growth first in numbers and secondly in interminable wants. Then, accepting the fact that the human race has grown exponentialoid, along with greater exponentialoid wants, the adaptation of artificial methods of for an artificial-sustainable future has become a must.

Nature has a way of interpreting 'sustainability' which is different than human's "artificial-sustainability.' Along these lines, nature's way of sustainability encompasses catastrophic implications to humans such as pandemics, draught, weather related disasters, etc… If we have crossed a threshold of natural feedbacks and checks and balances in what we are beginning to experience as adverse climate change, then the last 3000 years are no longer benchmarks for design and construction or for human expectations.

Leaving sustainability aside for the moment, there is the other issue of resource consumption that is taking place at a rate never experienced before. There are those that think that technology will save the day, however technology brought us to where we are and it seems that the world is bent on doing more of the same but at a much larger scale, the same electricity, the same steel, the same copper, the same aluminum, the same concrete etc, when the use of the 'same' is now exponentialoid. Then there are those that opinionate that we can find new sources of resources for the same construction as we have known, but will that last one hundred, one thousand, and ten thousand years? Then there are those that contend that we will find new materials.

Meanwhile we are blindly busy with transformation in the middle in so called 'sustainable' processes and high-performance green building, etc. It appears that we need to view artificial-sustainability with greater precision, first philosophically and then heuristically as the force that tames an artificial unsustainable exponentialoid and then we need to look in the face of the magnitude of that force to be tamed.

The next step in the argument is to tie population growth data with the events of the Industrial Revolution to see if we can determine the ‘elements that influenced’ the exponentialoid. The thrust of this approach is that by finding and understanding better the elements that so drastically affected nature’s sustainability and unleashed the exponentialoids, we can then transfer that new knowledge and see if we can identify the elements of influence of ‘change’ in building construction.

However, as stated, before we take that step, we need to better understand the concept of complexity because we are dealing with complex issues and then systemic nature of the industry because it is complex. We shall approach this work by analyzing and criticizing the founders of these theories. *Fig. 2.17* shows schematically where we are in this dissertation. *Fig. 5.2 “Intent Structure” Chapters and Relationships* characterize the flow of the dissertation. Chapter 2 is indicated to provide the foundation and theory for future work, while chapter 3 provides the literature search background, the systemic nature of the industry, systems thinking and the boundaries of the elements of influence.

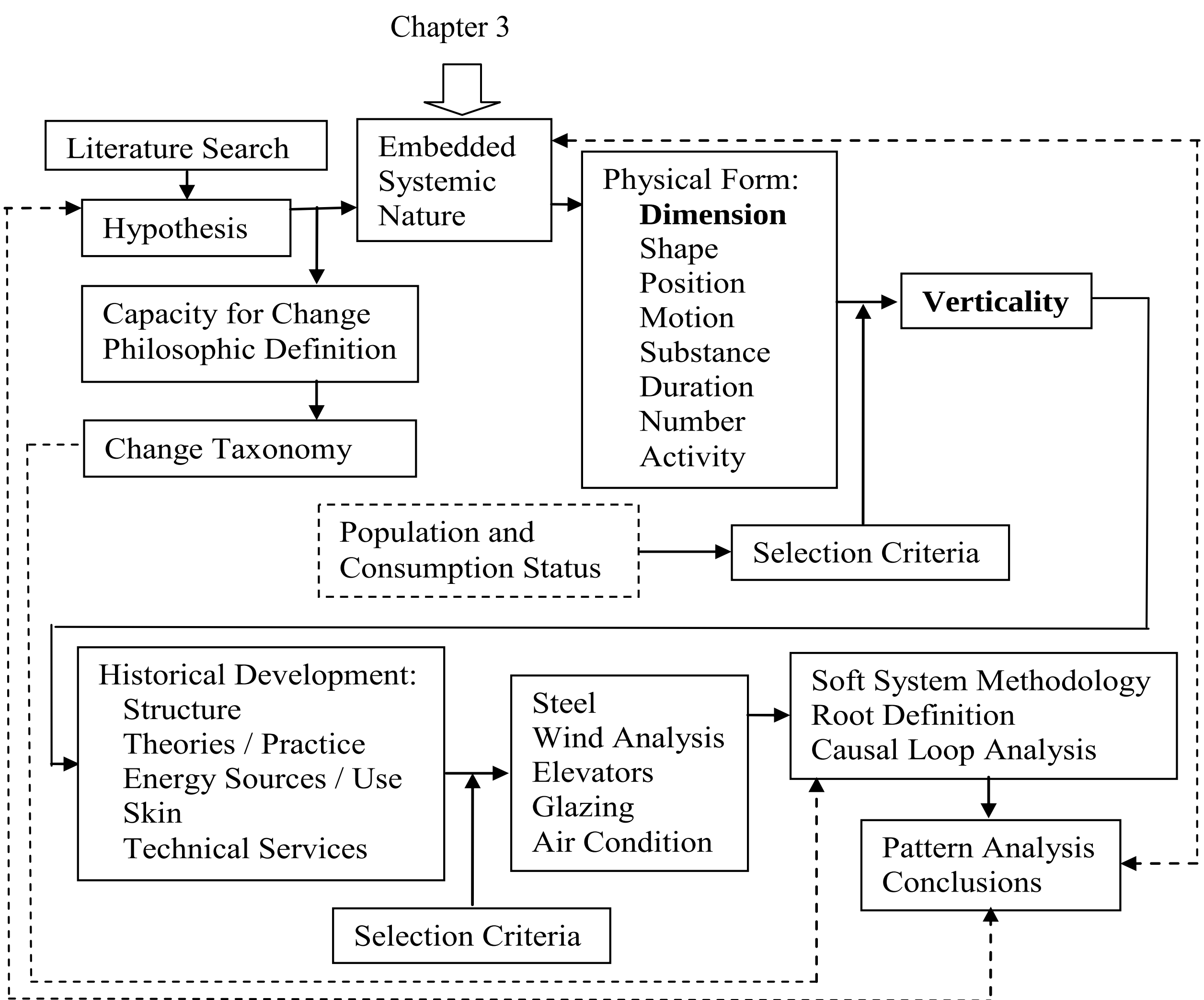

Fig. 2.17 Dissertation Schema: Population, Consumption and Natural Systems

CHAPTER 3

TOWARDS AN UNDERSTANDING OF THE SYSTEMIC NATURE OF THE BUILDING INDUSTRY

In chapters 1 and 2 we have articulated the following global challenges facing the industry: (i) projected population dynamic growth; (ii) affluence demographic growth; (iii) resource consumption (a form of inputs); (iv) emissions generation (part of the output). We limited our scope to building construction within the general construction industry. These four parameters and limiting scope form, at a macro level, the boundaries of our system of interest with the understanding that others have compiled different elements in their system of interest[99]. The trends were analyzed in Chapter 2 in the form of so-called "exponentialoids." In this chapter we will encounter the 'exponential' in the works of Forrester (1968, 1971), Sterman (2002), and Meadows (1972) adding credibility to the type of growth facing sustainability.

In this chapter, we are going to analyze past studies (that will lead to our present approach). Specifically we analyze the studies of Dr. Forrester and Dr. Sterman (J. W. Forrester Chair at MIT) to establish that these reliable studies address the identification of the challenges but fail to convince whether the required reductions in ecological impact can be realized to tame the observed growth rates. In other words: there are no available system representations of complex systems that can serve as the basis for studying long-term sustainability through the twenty-first Century. This lack of realistic system representation (worldview) is the major constraint, not the number crunching capabilities of technology for studying 'wicked' complex problems.

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[99] Hart 1997 identifies the main challenges: climate change, pollution, resource consumption, poverty and inequality; while Forrester 1968 identifies: population, natural resources, capital investment, agriculture as a sub set, and pollution.

The question we are going to focus on this chapter relate to the issue of 'complexity' in the natural and artificial environments. First, how pervious models address complexity and how the state of the art has evolved to understand the characteristics of complexity. What we have found in this study is that scientific models are primarily algorithmic in nature. The deeper meaning behind this statement is that although the model lends itself to computing techniques well, it does not capture complexity well, primarily because the worldview representations and because of the model innate limitations that we shall see further on.

In summary, Chapter 3 articulates that we live in a post-Forrester era in which hard dynamic systems are no longer accepted as adequate representations to study the dynamics of complex systems[100] such as economies and large industry sectors. Theories of Complexity (TOC) informs that uncertainties, capacity for self-organization, adaptability, inventions, economic conditions, entrepreneurship, the role of regulations, etc. call for 'types of thinking' that are not based on reductionism but analyzes complexity to its full extent. Based on this type of thinking we can identify a novel "worldview" of the building industry. The building industry systemic nature will be viewed through the framework provided by TOC.

The implications of these findings lead to the next steps: A historical search of the elements that influence change at a macro level, such as those that may be found through the analysis of the Industrial Revolution, the high-rise building, the air condition and the elevator sub-systems. If the elements of influence are found in all these levels, we may heuristically say that the state of the art, at this point in time, indicates these elements are a necessary and sufficient set that influence a system's capacity for change. Chapter 5 will tie the elements of

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[100] "System" defined as a set of different elements so connected or related to perform a unique function not performable by the elements alone.

influence, with one or more of the vectorial components, to lend credibility to the heuristic/theory and Chapter 6 draw conclusions and point to future work.

3.1 OBSERVED PAST BEHAVIOR THAT LEADS TO CURRENT APPROACH

"Systems Dynamics" is a term specified in a very particular area of study of systems, especially concerned with temporal feedback (Davidz et al 2006). This is the program of study originally promoted by Jay Forrester (MIT) and now championed by John Sterman (MIT) and followers.

According to Chu et al (2003), (i) there is no generally accepted definition of complexity, (ii) there is a search for an universal and unifying theory of complexity (TOC) that remains ideal in most scientific disciplines, and (iii) there is no simple universal criterion or litmus test to decide if a theory is scientific or not due to the range of varied domains that comprise science! On the other hand, there are grounded criteria that the *aim* of scientific theory should address which are discussed in this chapter.

"Complexity is connected by a net of intense interactions and mutual dependencies (contextuality) in a radically open system," a statement acknowledged by the scientists in question, but that fall short in actual practice probably due to the bias in the inherited paradigms. An example of the inherited paradigm (that bias our view of the issue surrounding sustainability) is that ultimately 'sustainable action' must take one of the following form: Increased efficiency through high-performance practices; Limiting and augmenting that which can be grown organically (i.e. forest woods, ethanol – grain alcohol) obtained from indefinite supply from nature (i.e. solar, wind, nuclear, hydrogen); Limiting or reducing energy requirements through technological advances; Limiting or decreasing consumption (the ecological footprint, Wackernagel et al., 1997, 2002; Van Vuuren and Bouwman 2005); Increasing reusability of what exists (i.e. recycle); Decreasing the inherent waste in current processes and systems; and others (such as: dematerialization, green design, collocation, and more efficient practices).

Individual and collective actions are supposed to somehow achieve some degree of sustainability, but there are three problems that need to be addressed: (i) There are no metrics of what is needed and how the aggregation of these complex actions achieve their intent; (ii) There is a serious doubt that this shotgun, cafeteria approach, (even if all the instruments for sustainability are performed at their highest level of possible efficiency and effectiveness and at a global scale) can significantly meet exponentialoid growth demands; (iii) Where can the burden be placed for changing a global paradigm (cultural, social, economic, etc)? Economists such as Pearce (2006) and Chichilnisky (1997) seek a global economic system to attribute the cost of pollution to common sinks such as the atmosphere and the oceans.

The current Carbon Trading program, influenced by Pearce's work, is an attempt to account and proportion some cost for excess carbon emissions. Pearce 2006 states that "the world as a whole seeks to convert the atmosphere from an 'open access' resource (one in which there are no owners at all), to a 'common property' resource, on in which there is a communal interest in avoiding depreciation. Moreover, policy instruments such as carbon taxes and tradable emissions permits are assets embodying permission to emit harmful gases" in exchange for some other form of capital benefit.

Current action is limited to the above plethora of solution scenarios. The FT 10/20/06 states that all alternative energy sources: everything from solar and wind to waves and waste, with the double digit growth in energy demand, is not forecast to make up more than 2% of the total energy mix by 2030. The current mix, projected to remain into the 2030's is of a third from oil, a fourth from coal, a fifth from gas and one fifteenth from nuclear with approximately 2% from all other. The center of the problem then is a worldview that does not understand the type and magnitude of required actions, understands the dynamics of growth mainly in terms of algorithmic equations,[101] and does not take into consideration the complex forces behind the reality that creates the problems. Forrester (1968, 1971), Sterman's (2002), Pearce's (2006) and Chichilnisky (1997) approaches to the issues are limited by a deficient worldview.

3.1.1 Forrester's approach

Forrester (1968) makes three general points: The world is a system, exponential growth can't continue, and a comprehensive approach is necessary. The intent of the following analysis is not to bash a 40 year old model and its descendants. This model was created as state of the art technology and heuristics in practice at that time and has served to bring global attention through publication and as the foundation for future work. Since this model informs current strategies to the problems, the worldview, the model and its internal mechanisms are of interest if we want to understand what was done, how and why to find a new way of approaching a worldview, model and mechanisms.

3.1.1.1 The world is a system

The world is a system is Forrester's cornerstone for identifying a structure and creating a systems model to represent it. Forrester (1968) in *The Principles of Systems* establishes the principle of 'structure' as fundamental for framing the principles of dynamic behavior. Forrester acknowledges the complexity (Waldrop 1992, Lucas 2000, 2004, 2005; Kauffman 1995) of social systems (Tavistock, 1996) that need to be understood in terms of 'principles to structure knowledge' so that they can be modeled in a system of dynamic behavior.

Specifically, Forrester uses the closed system of feedbacks that is influenced by *past behavior* and controls predictions. Feedback, in his model, can be positive or negative, where

[101] Algorithm is defined as a computer program with a fixed sequence of deterministic steps to follow.

negative feedback seeks a goal and responds as a consequence of failing to achieve the goal. Positive feedback generates growth processes wherein action builds a result that generate still greater action. Forrester's (1968, 1971) models treat the world as a closed continuous system and represent the identified 'important parameter' in the system.

Forrester created several models: The first model, named 'World 1' was the result of the meeting of the *Club of Rome* in 1970. Later on 'World 2' and 'World 3' were created with over 120 interdependent variables calibrated to historical trends. Variables which measure levels, sometimes known as 'state variables', are: population (P), natural resources (NR), capital investment (CI), pollution (POL) and the fraction of capital devoted to agriculture (CIAF). Each of these 'state variables' affects the change of the other variables through a set of relationships. It is the definition of these relationships, which reflects both the accuracy of the model and its actions. Small changes in a relationship between two states could cause vast changes in the forecasting action of the model.

The model was originally written in Dynamo and by now in other formats. This model was an important breakthrough in developing subsequent work. Forrester's (1961) *Industrial Dynamics*, (1968) *Principles of Systems*, (1968) *Urban Dynamics* and (1971) *World Dynamics* (1971), are interplay models between demographic, industrial, and agricultural sub-systems to study the rapidly growing stresses within our largest social system, the world community. These models, as indicated, are based on "Systems Dynamics" developed at the Massachusetts Institute of Technology. Forester saw models as the policy solution and felt that models could serve policy purposes even without good data (emphasis added).

The bounded and apparently self-closed Forrester model has some strengths and limitations. One limitation is the difficulty to identify and measure for all the necessary and sufficient "generators of complexity". It also fails in a proper understanding of their dynamical inter connections. These limitations are inherent to the very idea of a model itself where a relative small number of elements of a system are deemed to be relevant by the modeler when informed by a particular worldview. The formalization of the elements into mathematical equations (algorithms) constitutes a contribution of the Forrester model, although to some Forrester's real contribution is bring the problem to the forefront through publication. This selective representation of parameters (Chu et al. 2003) creates an 'impoverished' model when compared to reality, (with the caveat made by Chu, "*that this statement is true for any model*").

Reality, in a universal definition of a System of Interest (SoI), partitions the world into the system and its ambiance (or environment). The idealization process of modeling not only involves the simplification of the internal dynamics of the SoI but also the idealization of the system-ambiance (environment) interaction through a manifested worldview. This partition highlights the problems of radical openness and contextuality.

Radical openness: Modeling either ignores the system-ambiance interactions (such as in laboratory tests) or models them in terms of sinks (outputs) and sources (input) such as in Forrester (1971) model. Chu et al (2003) observes that no equivalent of ambiance as-it-actually-is can be present in the model because if it were, it would simply become an extra element of the system of interest, with an enlarged boundary but deficient in capturing the larger meta-system, the new ambience. Therefore, although systems such as Forrester's are nearly closed, they remain open in a real-world context, what is termed as "radical openness" and thus open to added complexity, additional unknown variables.

Radically open systems go beyond what can be represented by 'sinks' and 'sources' in a model. This radically openness is captured by the concept of meta-systems previously alluded where the whole is less than its parts, and contains absurdities and paradoxes. Radically openness is a direct consequence of the richness of the connections between systems and their ambiance, whereas contextuality captures the complexity of intra systems. The radical openness is reducible if the ambiance interactions can, for specific modeling purposes (especially on a specific spatial and temporal scale) be internalized (sinks and sources) by some choice of system boundaries. Important cases of irreducible radical openness are systems or domains that transform their ambience and are transformed by it on relevant temporal scale, such as natural systems or domains in the problem at hand.

Some choices of systems boundaries might be better than others and actually approximate quasi-closed systems on some spatial and temporal scales. In these cases we may consider the radical openness reducible, an option that Forester and his followers have taken.

Contextuality: is conceptually independent from radical openness and is an important concept in understanding Forrester's model. Contextuality implies that the same natural system may be studied and modeled using a number of different approaches. Accordingly, the models will focus on different aspects of the system-as-it-is and will be motivated by various interest, research programs, problem definition and world-views. Chu et al (2003) defines a system contextual if it includes one or more elements that also occur in a different system(s), or is in itself a shared element (generator of complexity) between more than one system; in this other system(s) the shared elements take part in causal processes different from those included in the original system.

Contextuality is a property that is a direct consequence of the partitioning of the world into systems and ambiance that precedes the modeling work. Contextuality is reducible if the contextual properties of a system can be disregarded for all practical purposes or the contextuality is purely internal (that is, if there are no contextual features with other systems that lie in the ambiance) and there is no causal connection between the phenomena in the SoI and the contextual features of the ambiance. In other words, systems contextuality often manifest themselves through elements that play multiple roles, fulfill several functions across the boundaries of the systems, or may be wholly irreducible in the sense that contextuality degenerates to a trivial property as in the case of may laboratory experiments.

Chu et al. (2003) further observes that contextuality in radically open systems (i.e. meta-systems) is a major source of unforeseen and potentially detrimental side effects (i.e. absurdities and paradoxes) of interventions into complex natural systems. Lack of attention to contextuality and the characteristics of radically open systems are examples of a deficient or outdated world-view interpretation.

The worldview, for example, that Forrester frequently uses implies that pollution will cause death and that efforts at population control are "inherently self-defeating". Forrester interprets crowding as a force that will affect exponential growth, but that has not been the case as urban developments continue to increase density never before observed, although it is possible that a threshold has not been reached where his postulation becomes a reality. This view has been dispelled by the current drastic Total Fertility Rate reduction; attributed by most to concerted efforts of contraceptives, abortions, women education and urbanization. The claim that "there may be no realistic hope of the present under-developed countries reaching the standard of living demonstrated by the present industrialized nations" has not materialized, when we consider the examples of China and India. "From the long view of hundred of years hence, the present efforts of underdeveloped countries to industrialize may be unwise." The underdeveloped world has answered in the negative and plowed ahead with the dramatic increases in living standard by developing countries' population.

The methodology employed by Forrester (1971), with closed feedback loops, does not take into account elements of social complexity that have been found to have significant impact in both creating the problem and in solving the problem. The feedback loops are structured on two kinds of variables: levels and rates. The levels are the accumulations (integrations) within the system. The rates are the flows that cause the levels to change. Again Forester speculates that "levels are cause to change only by the related rates of flow" stem from a deficient worldview, using only levels and rates in a schema where all systems change through time.

Also, the levels chosen as the cornerstones on which to build the system structure, are suspect, if not the underlying assumptions of the modes of behavior of interest and their interactions. The pollution loops, population controlled by crowding, pollution, and natural resources loops are suspect. The following "Proven Resource" loop (see *Fig. 3.1*) is an early version used in the Forrester model.

In Forrester's (1971) own words, a computer model embodies a theory of systems

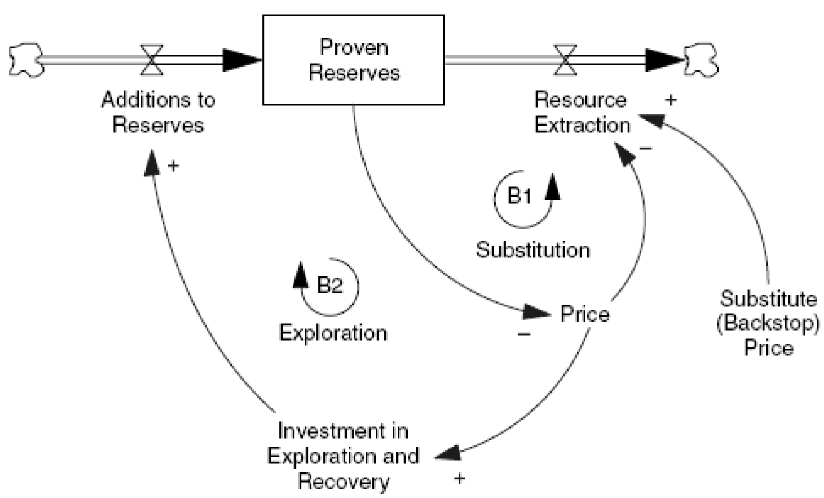

Fig. 3.1 Forrester partial model of resource consumption

structure (See *Fig. 3.1*). "The model is only as good as the theory which lies behind it. A good computer model is distinguished from a poor one because it captures more of the essence of the social system that it presumes to represent." We may add that his computer model captures the understanding of the social system workings at that time, but not the mature and magnitude of the exponentialoid force confronting his worldview of (artificial) sustainability, henceforth its Achilles heel.

Forrester (1968) "System Dynamics" model is based on the previously mentioned 'classical control theories'. A classical control theory premise is that the knowledge of the state of a closed system (at least a modeling system) accounts for the position and velocity of all its particles at any instant (algorithmically), which determines unambiguously the future motion of the system. However, the occurrence of probabilities is justified and therefore statistical methods are adopted (Born 1969) in an algorithmic framework.

Forrester's philosophy that informs his worldview has a pessimistic streak based on the inferred assumption that since we cannot control the variables, the present course is unsustainable. Sustainability efforts, in Forrester's view, even if well intended, can not tame the exponentialoids. "A major cut back of industrial activity, the treatment will at first seem as serious as the disease…" "Pollution generation declines as population falls…" "Exhausting natural resources creates population decrease…" "Technical solutions create pollution that creates population decrease…" "Crowding affects the quality of life and creates population decrease…" "Food shortages create population decrease…" "Each attempt to eliminate a pressure within the system leads to a new pressure" (possibly because of deficiencies in the structure of the model and the feedback loop arrangement!)

Although Forrester (1968) in his introduction to *World Dynamics* states that this model is offered as an interim "until a better model becomes available," his model contributed to accentuate a sense of urgency. Forrester, as noted, correctly makes three general points: The world is a system (treated in this section), exponential growth can't continue, and a comprehensive approach is necessary, the next points to consider.

3.1.1.2 Exponential Growth can't continue

Forrester (1971) assertion that "Exponential growth cannot continue forever" is a subjective observation statement. Exponential growth appears highly undesirable but Forrester offers no alternatives on how his elements that influence growth may apply sustainability forces to the exponential growth, that is: how the exponential growth may be tamed.

Forrester's understanding and model of the exponential is algorithmic based on an understanding of a world through a structure based on levels and flows as noted previously. Within the limited model, Forrester and followers solved the inverse problem, i.e. what has to change and how in order to avoid depletion, pollution, population explosion etc, but vitiated by the model assumptions, that is the informing worldview.

The work of Chichilnisky (1997) on *"What is Sustainable Development?"* although mostly in terms of her areas of expertise (Mathematics and Economics) alludes to an interpretation of consumption as a "vector" which is a quantum step in the understanding of the forces of sustainability, but also vitiated by embracing Forrester's worldview of the times.

A new model that fully takes into account the complexities of the human condition and especially the mechanisms for change is necessary to investigate if indeed humanity has the capacity to change and tame the exponentialoid. We expect that exponentialoids should be intrinsically vectorial in nature because it is caused by elements exhibiting the characteristics of complex systems. If this is the case, then the same elements that cause also modify the exponentialoids.

3.1.1.3 A comprehensive approach is necessary

Some, like Hart (1977), place the ultimate burden for achieving sustainability on an informed and motivated private sector; others, like Forrester (1968), place the hopes on the swelling of public political force affecting the governmental sector. Pearce (2006) and Chichilnisky (1997) place their hopes in adding the detrimental cost of emission to the accounting system employed by the General Economy.

Hart's hopes on the corporate world appear to be overtly optimistic: "corporations are the only organizations with the resources, the technology, the global reach, and, ultimately, the motivation to achieve sustainability." Sustainability of course as understood in the worldview of his times.

Regarding the public-governmental-political arena: Edwards (1996) observes that "most policies that make it through the policy process have certain characteristics: they have a narrow focus, a high probability of success, short-term payoffs, they are tangible, easily perceived, have widely derived benefits, perceived affordability, and feedbacks. Although models have a role in policymaking, the Forrester (1971) models, according to Edwards, did more in the arena of public opinion with the sale of more than seven million copies of *Limits to Growth* in more than 30 languages, than in policy making. According to Edwards (1996), "*Models-for-policy should be used heuristically, not predictively.*"

We concur that a heuristic comprehensive approach is necessary, one that moves both the private and public sectors. However there is also a large gap on wishful thinking that problem clarity will effect the intended changes. In other words, private and public opinion and policy are complex components.

3.1.2 Sterman's approach

Sterman (2002) continues Forrester's (1969) work and has moved from a 'Systems Dynamic', mechanistic and reductionist approach to a more 'systems thinking' approach that attempts to take into consideration the complexities of the human condition. Sterman's model evolves in a worldview that establishes the link between the soft systems and the hard systems methodologies akin to that of Forrester.

The emphasis on this approach is on finding a process for understanding the dynamic behavior of our social systems, thus the work remains significant, but at the level of 'systems thinking,' 'systems dynamics,' 'classical control theories,' 'artifacts' (Strand et al 1996). *Fig. 3.2* is an updated Forrester loop for Resource Consumption as interpreted by Sterman.

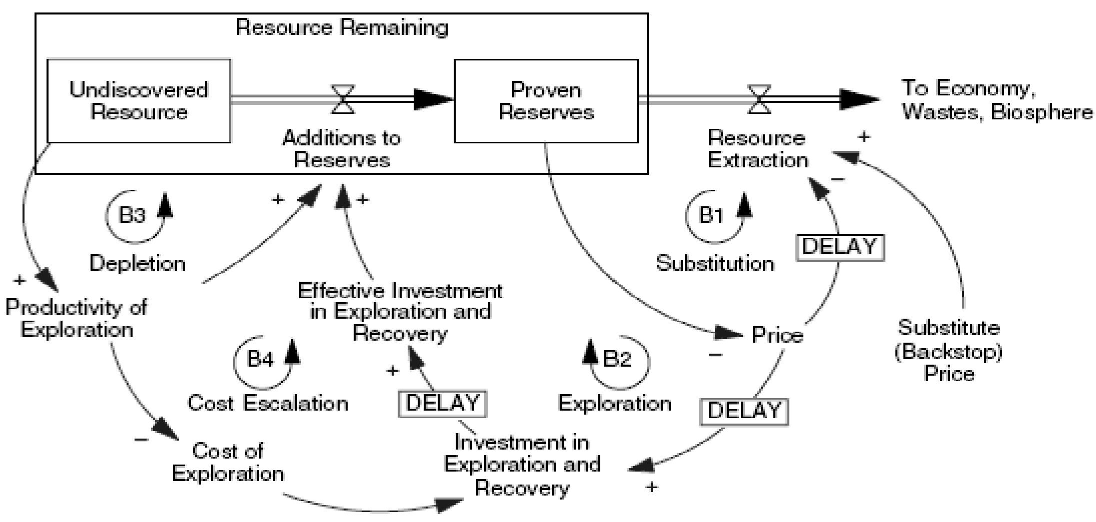

Fig.3.2 Sterman's elaboration of Forrester's partial model of resources

3.1.3 Summary

Forrester's (1969) and Sterman's (2002) formal model are closed systems by their own admission, well defined (have clear boundaries) are self-contained (in the sense that any transformation or state of changes of the system or parts of it are internal or due to a well defined input function). As such it is a model not embedded in an ambiance but has internalized a highly abstract representation of the ambiance (sinks and sources). In a sense, a risk was taken when idealizing a world-view to study something overly artificial and producing an 'artifact'. Regarding contextuality as defined, the main question for Forrester's and Sterman's model is whether the specific aspects (generators of complexity) chosen are the necessary and sufficient set needed to understand all the consequences they cause. Failure to do so, in Chu's et al (2003) words, results in 'impoverished' models even though as duly noted, it was the state of the art at that point in time, and thus a major milestone in creating strategic thinking and marshalling public opinion to address the problems. In other words we need a model that as an abstraction is a better idealization in our evolved understanding of complex reality.

The position of this dissertation is that concurrent to better understanding of the dynamic behavior of our social systems is a worldview of the dynamics of social and artificial systems. Such worldview is informed by philosophy as well as historical thinking before a commitment is made to a hard system since according to chaos theories (Lorentz, 1972, 1993; Gleick, 1987; Thiétart and Forgues 1995), the wrong assumptions at the beginning will have severe impact on the outcome.

Because time is of the essence, we must devote an inordinate amount of time and effort to the identification and clarification of a worldview where the already identified exponential growth, the concepts embraced by the term Sustainability, the elements that influence the forces of sustainability or lack thereof and the forces that have historically moved those elements are understood. This worldview is used to construct a model of the relationship between exponentialoid growth and sustainability using the elements that influence the exponentialoid growth in order to study adequate responses.

However, before approaching a new worldview, we need to determine how we postulate a type of system to be the right vehicle to study a phenomenon that cannot be extrapolated from past behavior, in other words, what is the criteria for drawing boundaries that capture the necessary and sufficient elements.

3.2 HOW CAN WE POSTULATE A TYPE OF SYSTEM TO BE THE RIGHT VEHICLE TO STUDY A PHENOMENON THAT CANNOT BE EXTRAPOLATED FROM PAST BEHAVIOR?

For the aim of this dissertation, to determine the underlying mechanisms and forces of an unsustainable exponentialoid, we need a better understanding of the complex nature of the building industry. A worldview of the industry with its complexity provides a more realistic platform from where we can identify the elements that historically have influence industrial change and avoid the attraction and bias of reductionist models such as Forester's and Sterman's. For example, if the mechanisms and forces that engender an exponentialoid that affects building construction are not related to the forces that engender change in building construction then we do not have an observable a relation between an exponentialoid and building construction. In other words, the mechanisms and forces that create an exponentialoid are multiple and complex.

The complexity of the building industry needs to be better understood so that the mechanisms and forces that create change in the industry can be discerned. Once these two items are in place we then proceed with pre-paradigmatic, analogue thinking to construct the rules for a bridge between them. Without a full appreciation and understanding of the complexity as a main ingredient of building construction, the inquiry of this dissertation will fall short at one end in this gap of knowledge.

The models of these other industries would have been satisfactory to manage complexity and the drivers of change if building construction has the characteristic of other mass production industries. However if building construction does not has the characteristics of other mass production industries, then a new model is needed to understand complexity and the drivers of change. Likewise, if building construction is not akin to manufacturing, and there are no models, we need to go one layer of knowledge higher and discern a worldview (paradigm) that allows us to realistically look at the industry (Ranta 1993). In this case, we may even have to go back into another layer of knowledge, the archives of philosophy and the tools of metaphysics and epistemology to clarify the foundational concepts that inform a pre-paradigm. Therefore a clear distinction of the mechanisms and forces of manufacturing vs. building construction is cardinal, hinge, to our dissertation.

Two main aspects of a worldview are of particular interest and in need of better definition: One relates to an understanding of the systemic nature of building construction as an 'industry' and the other are the 'characteristics of complexity'.

In Chapter 4, we shall postulate the intertwined, dynamic, complex characteristics of building construction (Nam and Tatum 1988) where we observe a paradoxical co-dependency of project and process. Furthermore we have alluded in previous chapters, and will postulate in Chapter 4, that building construction and construction in general does not behave as an 'industry' but more like a 'conglomerate of industries', an 'industry of industries', a 'meta-industry' that according to Palmer (2003, 2004) includes holes, absurdities, inefficiencies, and paradoxes as well as the capacity to invent and innovate. If this is the case, past behavior of specific industries is not directly translatable to the behavior of a meta-industry. This line of generic and structural thinking regarding complexity and the systemic nature of building construction as a meta-industry requires additional foundational work.

3.2.1 Towards an understanding of the systemic nature of the industry

Koen (2003) succinctly states that the engineering method under which building construction method can be located is based on 'change', utilizing available resources, with a method based on some 'particular rationality' (albeit heuristic rather than scientific in his view) derived from 'the state of the art' at that point in time, directed towards a 'best or optimum solution,' but always occurring in an 'environment of uncertainty.' All types of engineering, science, philosophies fall under the category of heuristics, according to Koen (2003). Koen proposes the following example of heuristic rationality: "*at the appropriate point in a project, freeze the design; allocate resources as long as the cost of not knowing exceeds the cost of finding out; allocate sufficient resources to the weak link; and solve problems by successive approximation*." The following is Koen's definition of heuristics: Anything that provides a plausible aid or direction in the solution of a problem but is in the final analysis unjustified, incapable of justification, and potentially fallible with the following signatures:

- A heuristics does not guarantee a solution
- It may contradict other heuristics
- It reduces the search time for solving a problem
- Its acceptance depends on the immediate context instead of an absolute stand

Regarding our understanding of heuristics in this dissertation, for example, the ability to try to solve unsolvable problems (such as complex problems) or to reduce the search time for a satisfactory solution is a characteristic by which a heuristic may be recognized. In Koen's words: "Some problems are so serious and the appropriate scientific technique to solve them are either none-existent or so time consuming that a heuristic solution is preferable to no at all." His words echo Descartes 1989 (Cottingham 1986): "Situations in life often permit no delay; and when we cannot determine the method which is certainly best, we must follow the one which is probably the best…if the method selected is not indeed a good one, at last the reasons for selecting it are excellent.”

In a construction project, uncertainties (Bertelsen 2005, 2003) are due to temporary coalitions in a turbulent environment requiring semi-predictable or even unpredictable configurations of supply industries and technical skills. Groák (1992), Polanyi (1967, 1974), and call these ‘technological paradigms’ organized around a ‘project’ and not the ‘firm or productions process’ (Nightingale 2000) a major paradoxical distinction between construction and manufacturing. Paradoxically, as we shall see in more detail later on, because although the axis of a project is essential, the defining characteristic of the systemic nature of building construction, is a ‘dynamic process.’ (This dynamic process is similar to Hawkin’s (1998) paradox: a moving train where a passenger and a platform viewer have different perspectives of the same event).

A clear distinction between construction and the traditional definition of an industry, like manufacturing, is essential for an understanding of the systemic nature of the ‘industry.’ The capacity of the industry (Hillebrandt, 1975, quoted by Pearce 2006) is revealed in the use of different distinct resources and skill bases for different building types and different construction sectors (civil, building, industrial, manufacturing, housing, medical, etc.) These construction sectors are in fact different ‘industries,’ according to Kodama (1992): “We are moving away from the idea of ‘one technology, one industry’ as the framework of analysis for building construction capacity for change.” Furthermore, not only are we moving away from an understanding of construction as encompassing one industry, but of several industries (Kodama 1992) from altogether the model of an ‘industry’ as understood in manufacturing and defined by ‘industrial science’ theories and practices.

Groák states “we should no longer treat construction activities as belonging to ‘an industry’ with definable boundaries, specific technical skills and using specific resources.” The focus should be more towards its end-products and services, recognizing increasing external linkages and potential innovations from beyond ‘construction’ where the construction capacity resides according to Hillebrandt’s (1975), a position embraced by Pearce (2003, 2006) and followers.

Although we concur with Kodama (1992) and Groák (1994) and appreciate the direction on building construction capacity for change, our position is that the concept of a meta-industry contains a world of paradoxical order and disorder that has not been explored as a better descriptor of the essence and processes that encompassed in the notion known as ‘building construction.’

3.2.2 Metaphysical basis for distinctions between product and processes

The reason for this metaphysical excursion is to create as firm a foundation as possible for a worldview of building construction that is based on the state of the art heuristics in our evolutionary process.

Koskela and Kagioglou 2006, elucidate how philosophy (which until recently was considered an obscure and antiquated field of knowledge, and according to some, superseded by science and technology) influences worldview, which trickles down on Science, Technology, Processes and Products (Nightingale 2000). Recently the study of metaphysics (Doyle 2004), an ancient and venerable branch of philosophy (Hegel 1975) that investigates the fundamental nature of reality, has started to flourish again (Price 1977; Craig 2000; Roochnick 2004; Palmer 2001b, 2004 and others).

Koskela and Kagioglou’s (2006) research states that since the pre-Socratic period, there have been two basic metaphysical worldviews. One holds that there are substances of things (being), that is, atemporal entities in the world. The other insists that there are processes (becoming), that is, intrinsically temporal phenomena. These metaphysical assumptions (things, being, entities – products; becoming, atemporal – processes) tend to strongly influence how the subject of the inquiry or action is conceptualized.

The thing-oriented view seems to lead to analytical decomposition, the requirement or assumption of certainty and a historical-philosophical approach. On the other hand, the process-oriented view is related to a holistic orientation, acknowledgement of uncertainty and to a historical and contextual approach.

Koskela and Kagioglou (2006) argue that 'production' is intrinsically a process-oriented endeavor. However, an analysis of current conceptualizations and methods shows that it is the thing-oriented view of the world (product) that has dominated research and practice of production management (Nightingale 2000). What the authors mean by this is that research and production management practices have used the Cartesian method of problem decomposition (Descartes' second rule, (1898), quoted in Cottingham 1986). Thus, according to Koskela and Kagioglou (2006), the general direction of research (and we may add production management) is achieved by going into even smaller parts of the whole and searching for explanations at the lowest possible level as used by Newton and followers, also known as the scientific approach.

The two underlying assumptions behind the thing-oriented worldview as related to decomposition are: (i) similarity and (ii) independence of decomposed elements or parts. Koskela and Kagioglou (2006) state: "the similarity assumption takes it for granted that the parts are, by nature, similar to the whole and thus also mutually similar. The assumption of the independence of parts follows from the similarity assumptions. Namely, if our unit of analysis is an idea, problem or thing in itself, so will all decomposed parts also be ideas problems or things in themselves.”

On the other hand, process metaphysics holds that ‘everything flows’ and is ‘change’. According to Rescher (2000) contemporary understanding of process metaphysics, as quoted by Koskela and Kagioglou (2006):

- Time and change are among the principal categories of metaphysical understanding
- Processes are more fundamental than things (i.e. Projects) for the purposes of ontological theory
- Contingency, emergence, novelty and creativity are fundamental categories of (process) metaphysics

Rescher (2000) defines process as a structured sequence of successive stages or phases, having three characteristics (thus establishing the criteria for processes):

- That a process is a complex; a unity of distinct stages or phases (a process is always a matter of now this, then that)
- That this complex has a certain temporal coherence and unity, and that the processes accordingly have an ineliminable temporal dimension
- That a process has a structure, a formal generic format in virtue of which every concrete process is equipped with a shape or format.

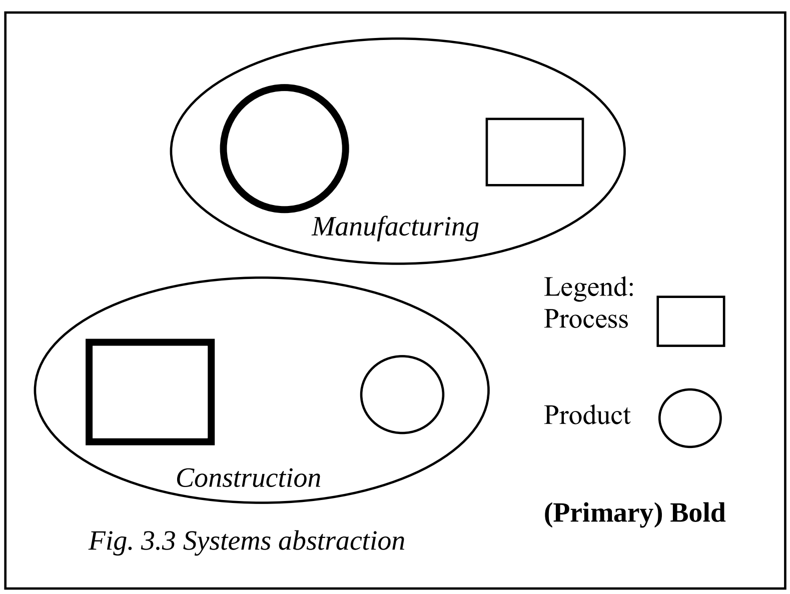

Fig. 3.3 Systems abstraction

3.2.3 Philosophical understanding of capacity for change

From a pure philosophical perspective 'capacity for change' is succinctly defined using Popper's (1972) method of analysis: Capacity for change is a concept defined with philosophical language, constructed by a subjective mind. In Koen's (2003) all-is heuristic worldview 'capacity for change' and 'change' are both part of a universal heuristic, period. No further derivation or definition is needed.

Construction, to build, as a verb, an activity, is about 'change'. To have a building is to have first the activity that created a building as understood by Aristotle, *"Nicomachean Ethics," 2.1.1103a35*: "Human beings become builders by building." Imai's (1986) Kaizen observes that there are two types of changes: abrupt change such as the difference between two sets of things i.e. the natural and the artificial environment and change the process between the now and the after now (see *Fig. 1.7, Change Taxonomy)*. Changes occur at a macro level such as industry, economy, social and micro level such as the firm, project specific organization and the project itself. The essence of this activity is environmental change, where there was nothing, now there is a building, through the process of construction. Because the arena of the change is the natural environment with an artificial environment it can be argued that building construction as well as construction in general is a processes, but with a project (read product) as its essential secondary axis. As a process, it is always 'now this, then that'; it is complex as we have noted, with a temporal and ineliminable spatial-temporal dimension; furthermore the building construction process has a structure. In contrast, manufacturing is a product but with a process as its essential secondary axis. (See *Fig. 3.3 Systems abstractions and Fig. 3.4 Building Construction abstraction*).

Mass product manufacturing is a tightly coupled system (with product in its main axis and process as the enabling characteristic) whereas Building Construction is a loosely coupled system (Dubois and Gadde, 2000), a process in its main axis and product which highlights the difference in the two systems (Nightingale 2000).

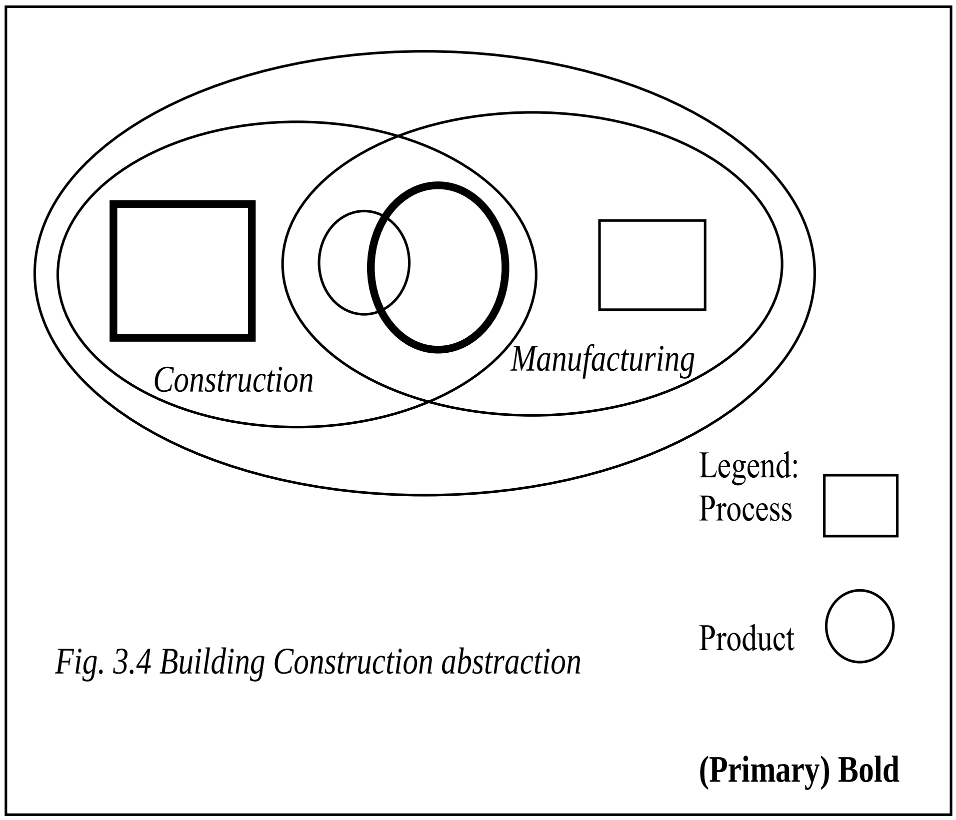

Fig. 3.4 Building Construction abstraction

Mass product manufacturing as a tightly coupled industrial system exhibits the following characteristics:

- Delays are not allowed or possible
- Sequence of events are invariant
- Alternative paths are tightly controlled or not available
- There is little or no opportunity for substitution or repair (usual discarded, wasted)
- Slack is not desirable
- Redundancies are designed and deliberate

In contrast, building construction as a loosely coupled system exhibits the following characteristics (Dubois and Gadde 2002; Nam and Tatum 1988):

- Number of permutations and possible combinations are enormous (Weick 1976, 1990)
- Complex operations (Gidado 1996)
- Inefficient operations (Cox and Townsend 1998)
- Sub-optimization (Gann 1996)
- Some tightly coupled, some time sensitive specialized activities with sequentially interdependent activities with standard parts (Gidado 1996)
- Mostly, it is a loosely coupled systems (Dubois and Gadde 2002)
- Overlapping activities; long lead time and slack built in
- Adaptive on-site changes (Vrijhoef and Koskela 2005a) and consequential changes (Crichton 1966)
- Generation of variations (Akintoye et al 2000)
- Self-determination; Coordination with different firms each adding a measure of slack
- Work is redone when non-conforming rather than product discarded as in manufacturing

It is reasonable to infer that building construction as a process is bounded at the upper end of the taxonomy by systems and meta-systems with complex process driven entities (see *Fig. 3.3*). However, at the same time, the boundaries at the lower end are assemblies that are product driven entities, (see *Fig. 3.4*). Perhaps this duality of process and product underlies the thinking of the proponents that want to make building construction more like manufacturing product driven.

Building construction's capacity for change is therefore an intrinsic a source as well as a recipient of variability, inefficiency, non-linearity, and comfortable with chaos, creativity, novelty, uniqueness and even paradoxes and ambiguities. A high capacity for change implies freedom at many levels of the taxonomy. In other words, the meta-systems nesting allow a high degree of inventiveness promotes creativity and celebrates diversity.

The capacity for change is furthermore exacerbated from the product end and the client himself as a complex system, source of variability (Cherns and Bryant 1984; Pries et al. 2004). This 'product' axis of the paradox also exhibits the characteristics of: uniqueness, expression, one-of-a-kind, on a particular site with particular characteristics, actors selected and acting autonomously (Koskela 2000).

It is then prudent to say that from both the supply and the demand side, from the process as well as from the product, and as a matter of fact from the milieu where building construction takes place itself, the universe of a meta-industry, that the fundamental characteristics of building construction are those of a complex system, process driven with a normative capacity for change.

3.2.4 Towards an understanding of the complex nature of the industry

According to Chu et al (2003) there is no generally accepted definition of complexity, there is no universal[102] and unified theory of complexity and that according to critics complex systems are too diverse to share any profound 'common causes for common characteristics'. Furthermore Chu has also observes that at a higher level in the field of the philosophy of science there is no unique, simple criterion or litmus test to decide if a theory is scientific or not. Thus rather than looking for a universal criteria for being scientific, it is often better to ground criteria in the *aim* of the theory or a heuristic (Koen 2003). According to Chu et al. 2003, three *aims* are central:

[102] Bak's (1987, 1993, 1994, 1997) "self-organizing criticality (SOC) which was proposed as a universal source of complexity has been repeatedly criticized (Sneppen et al 1996; Newman 1996) and is now essentially rejected (Chu et al 2003). Currently a well regarded candidate for a unifying notion of complexity is that of Complex Adaptive Systems (CAS) of Holland (1994) but with critics.

- **Predictive component**: prediction of the future behavior of a system[103] given a set of observational data about it; it is an active quantitative prediction and experimental manipulation of phenomena.
- **Exploratory component**: theoretical understanding and/or explanatory description of a system / framework for a number of phenomena
- **Control component**: provision of guidelines and control mechanisms for the intervention and manipulation of a system; ability to manipulate the exploitation of scientific theory.

Ideally then, a scientific theory would explain, predict, and facilitate control at the same time. However, all scientific theories do not follow the list of all mentioned components but may emphasize one of those components while the others are treated as negligible factors.

Chu et al. (2003), in addition to the above criteria, makes the following pertinent observations (emphasis added):

> "A central and related issue is the language in which a TOC is to be formulated. Science is largely dominated by a Platonist ideal (Koyre 1968). The essence of this ideal was established in mechanics by Galileo and its most important success is… theoretical physics. Often a TOC is (more or less tacitly) assumed to be a mathematical theory (Gödel 1931). Holland, for example points out that the mathematical form has the additional advantage of high precision and generalization. One may add that prospects of prediction and control might look better if a mathematical form is possible. Indeed quantum theory is wholly formalized and quantitative. In contrast, the theory of biological evolution by means of natural selection, for example, involves mathematics only for the formulation of detail, whereas the main insight is formulated in natural language. A TOC might be of this latter kind."

Borrowing from Koen (2003) TOC might be realistically considered as 'heuristic.' The additional observation by Chu et al. (2003), reiterated by others as noted in this dissertation is: "*Another element that is tightly woven into a Platonistic/Galilean paradigm is the idea that natural systems can be separated into relatively simple essence plus irrelevant perturbation or 'friction.' The latter acts like a curtain to hide the basic principles of nature's workings*."

Another important property of TOC is universality: A TOC should be applicable to, if not all, of a wide range of different complex systems. Chu et al. (2003) states that "*in a*

[103] System is used interchangeably with meta-system in this context.

Platonist/Galilean science tradition the idea of 'universal theories' is often equated with 'unified theories.' Although unification is of a highly aesthetic value, it should not be regarded as a litmus test for a universal TOC."

In summary: We would expect a TOC to be useful in: controlling natural systems, or to be predictive, or to be explanatory. It should make some claim of universality. However one would expect a possible trade-off between universality and mathematical quantitativeness and may or may not exhibit 'unification' characteristics.

3.3 SYSTEMS THINKING AND THE BUILDING INDUSTRY

Richmond (1993) uses the term 'Systems Thinking" as a replacement for (in an effort to separate his work from) the term "systems dynamics." Nevertheless, Sterman (2002) now uses Richmond's definition of systems thinking. Richmond suggests seven critical 'systems thinking' skills and the need to operate on all seven thinking tracks simultaneously. Other proponents of systems thinking or similar approaches are: Moti Frank's Engineering Systems Thinking; Peter Senge's (1994) Systems Thinking as one discipline of a Learning Organization (Edmondson and Moingeon 1998); Ludwig von Bertalanffy's Open Systems Theory; Stafford Beer's Organization Cybernetics; Russell Ackoff's Interactive Planning; Peter Checkland's Soft Systems Approach and C. West Churchman's Critical Systemic Thinking.

The term "systems thinking" is somewhat a paradox (Davidz et al. 2006; Zemke 2001), since this phrase combines words that imply individual and multi-actor concepts into one research construct. This creates difficulties in selecting the unit and level of analysis: A unit of analysis is the entity being described or analyzed during a research study (in construction the unit and level of analysis can be: macro - industry; and micro - project and firm); Four standard levels of analysis in social sciences are individuals (such as inventors, entrepreneurs); groups (such as social and cultural groups); organizations (such as building construction); and environments (such as the natural and artificial environments). Individual characteristics, group dynamics, organizational culture, and surrounding environments all affect the system of interest in multi-level interactions thus in a 'wicked' problem atmosphere. In this dissertation we have identified 'elements of influence' as one of the unit of analysis and thus it can be an individual person, a relationship, a social grouping, an organization, sector etc. These 'elements of influence' are each a 'generator of complexity' in a radically open system with the innate characteristic of contextuality.

Richmond (1993) suggested seven critical systems thinking skills which are as follow: dynamic thinking, closed-loop thinking, generic thinking, structural thinking, operational thinking, continuum thinking and scientific thinking. As mentioned, Richmond suggests that good "systems thinking" tracks simultaneously all seven skills. However, before we attempt to apply these seven "systems thinking" skills we must make some observations on the nature of the building industry.

3.3.1 Observations on the nature of the building industry (what are the unrecognized or unrecognizable complexity in systems)

Complexity in building construction (Bertelsen 2005) has been studied from different perspectives, for example: as part of managing complexity in project production (Bertelsen and Koskela, 2002, 2005), and the client as a complex system (Bertelsen and Emmitt, 2005; Emmitt 2003; Bertelsen 2003; Lucas 2004, 2005; Pries et al. 2004).

Managing complexity in project production is an attempt (Shewhart 1931; Shewhart and Deming 1939) to minimize variability to get the productive activity under control. The aim of this approach is to avoid complexity and uncertainty, which could disturb tight controls.

Recently this approach is championed in Lean Construction (Alarcon 1997; Ballard, et al. 2002), Last Planner[104] and Just in Time theories and practices. However, as noted by Bertelsen (2005), there are production situations with inherent complexity and unpredictability that escape efforts at reducing complexity, codifying procedures and learning to improvise and buffering.

These approaches result in a paradoxical inverse linkage with effectiveness and efficiency. Efforts at reducing complexity also rub against the nature of a meta-system characterized by a fertile breeding ground for inventions and innovations where technologies created for other sectors are adopted and assimilated successfully. In other words, control of waste is the opposite of variability and variability is the breeding ground of possibilities. Hence Building Construction has unrecognizable and unrecognized complexity as in a 'meta-system' and acts more like a complex, dynamic, living organism that is self-organizing (Kaufman, 1993), and adaptive as in a learning organization rich with waste and with innovation possibilities.

Client complexity (Pries et al. 2004), and its significant consequences, showcases chaos theories where lack of initial definition or moving targets along the phases create ripe conditions for divergence, as will be noted later on. First, we shall investigate in greater depth the understanding of complexity, in specific relation to building construction, as published in refereed journals.

Complexity according to Baccarini (1996) can be operationalized in terms of differentiation and interdependency. Some authors such as Waldrop, 1992, Lorenz, 1993 and Kauffman (1995) state: "complexity lacks a generally accepted comprehensive definition". Bertelsen (2005) asserts that almost any system can be seen as being complex. In this light, complex systems are not a special class of systems, but a way of looking upon any system as

[104] Lean Construction and Last Planner are a service trademark of the Lean Construction Institute, USA (Ballard

opposite to the ordered, reductionist worldview where systems are decomposed into parts that are analyzed with the expectation that the parts reveal the system and vice versa. In this context complexity studies mean studying the system as a whole without simplifications and observing the interactions between elements and systems as much as the elements and systems themselves.

This approach is characterized by non-linearity and richness in feedback loops where a formal analytic approach is no longer possible or desirable. A new schema for looking at complex system is provided by Lucas (2000) who identifies a comprehensive list of 18 characteristics found in complex systems. This list is considered by other researchers (Bertelsen 2005) as fairly exhaustive. A closer examination of these characteristics as related to building construction, allows a grouping in three categories: Autonomous Agents; Undefined Values and Non-Linearity. Furthermore Bertelsen 2005 relates these types to one of the three aspects of construction advanced by Koskela (2000): Transformation, Value and Flow from a construction process perspective.

However, what is considered a holistic, systems view, is also considered a reductionist view when the boundaries of the point of perspective are re-drawn. Two examples are proposed, one of the Aircraft industry and the other for the Construction industry. Davidz (2006) supplies the following example that has been adapted: Consider an aircraft engine: a "system" could be a part (a set of compressor blades called the compressor stage), a component (a compressor), a sub-system (an aircraft engine), a production system (an aircraft), a group of design engineers (Advanced Compressor Design), a business (GE Aircraft Engineers), a larger business (GE), a sector (the aerospace sector), a national general economy (USA), or the global system (air

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2000)

transportation). The definition of a system and the point of view that makes it holistic is therefore driven by the end-state or application of interest.

Building construction, in contrast, has a motor as component, a production system (mechanical system), a business (air conditioning) a larger business (a building) that has multiple and disparate systems (elevator, plumbing, electrical, structural etc.) that makes it a meta-system, is part of the building sector, part of construction, a national general economy and the global system of satisfying the human needs for security and shelter from the natural environment.

In the general schema proposed in earlier chapters, the building construction fits as follows (see *Fig. 3.5 Proposed general taxonomy*).

Building construction (as part of Construction in general, not shown for clarity) is listed as a sub set of the Industrial Sector of the General Economy. The industrial sector forms also the background from where the systems components, sub-systems, suppliers, vendors and manufacturers reside. Hence Building construction, a dynamic process that we have seen, is bracketed by the notion or reality implied in the word 'industry.'

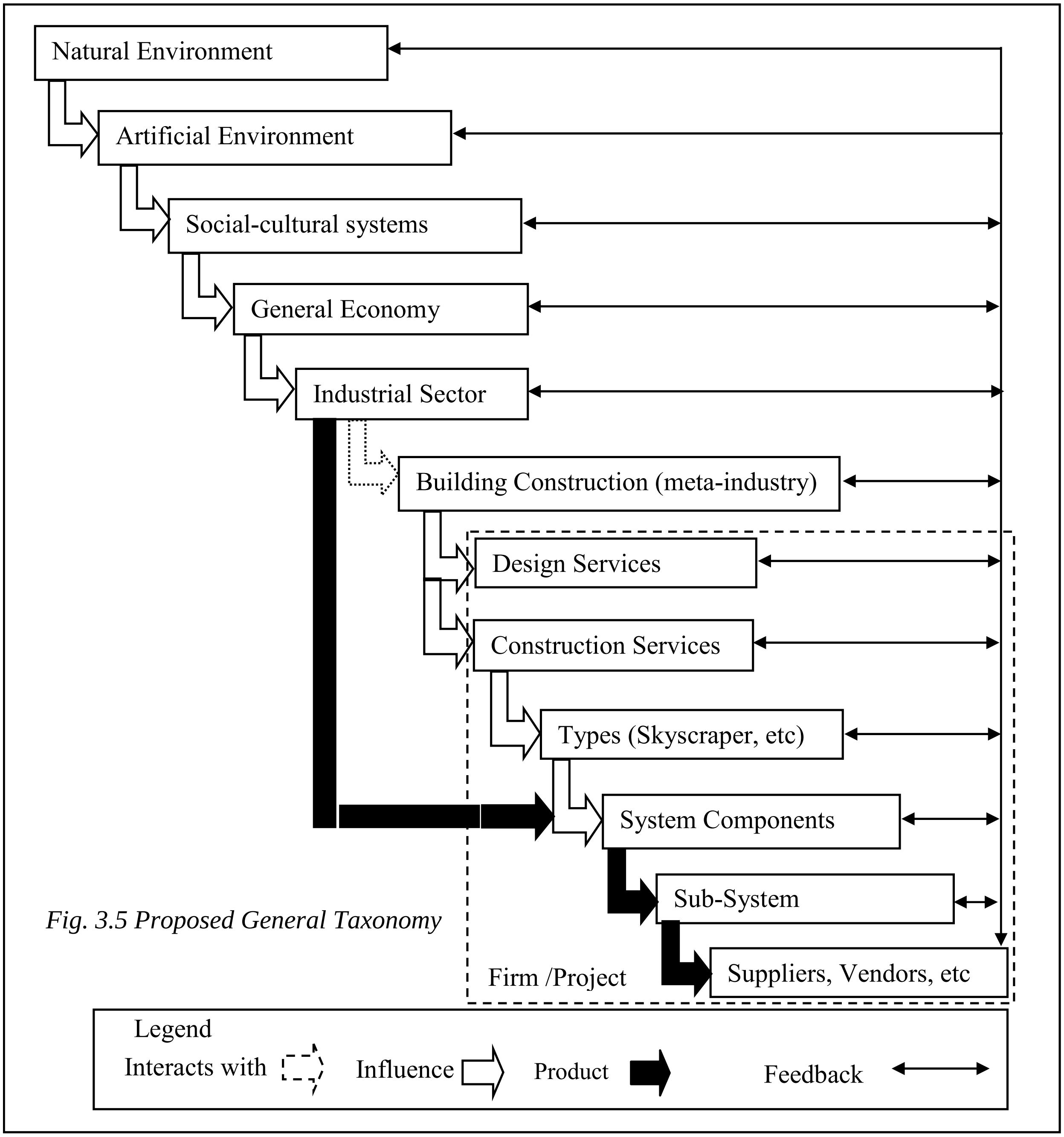


Fig. 3.5 Proposed General Taxonomy

Bertelsen (2005) groups 14 of the complex systems characteristics (taken from Lucas 2004; Nam and Tatum 1988) into the three alluded categories. We have taken this list, expanded to the full 18 elements from Lucas (2000, 2004, 2005) and added information from Koskela (2000) and Shingo (1988).

Table 3.1 Complex Systems		
Koskela: Transformation Shingo: Operations	Value Value	Flow Process
1.1 Autonomous Agents	2.1 Undefined Values	3.1 Non-Linearity
1.2 Non Standard	2.2 Fitness Landscape	3.2 Emergence
1.3 Co-Evolution	2.3 Non-Uniform	3.3 Attractors
1.4 Self-Modification		3.4 Phase Changes
1.5 Downward Causation		3.5 Unpredictability
1.6 Self-reproduction		3.6 Instability (variability)
1.7 Mutability		3.7 Learning Organization
1.8 Fuzzy Functions		

The following expands Lucas' definition of the elements found in a complex system:

1.1 **Autonomous Agents**: Stakeholders are varied, not identical, with differing perspectives and interests, which change over time.
1.2 **Non-Standard**: The system is heterogeneous and allows varying associations over time.
1.3 **Co-Evolution** (self-organization): The parts may evolve in conjunction with each other in order to fit into a wider system.
1.4 **Self-Modification**: Parts can change their associations or connectivity freely.
1.5 **Downward Causation**: A system is made up of its parts, and the parts are affected by the emergent properties of the whole system.
1.6 **Self-Reproduction**: The system can replicate itself.
1.7 **Mutability**: Random interval changes may occur in the system.
1.8 **Fuzzy Functions**: The overall function (purpose) of the system is co-evolved.

2.1 **Undefined Values**: The meaning of the system's interface with its environment is not specified at the outset

2.2 **Fitness**: The distribution of choices can be modeled using the concept of fitness landscapes, with local optima and global optimum that are relative and dynamic

2.3 **Non-Uniform**: The system is different and evolves in time in response to internal and external demands.

3.1 **Non-Linearity** (non-equilibrium): The system operates far from equilibrium since it takes energy from its environment

3.2 **Emergence**: System properties are higher-level meta-systemic functions of the system (Peitgen, 1986); Emergent phenomena travel from specifics to generalities and vice versa as well as from systems to ambiance and vice versa.

3.3 **Attractors**: The system has multiple dynamic attractors; it can be stable for a while, but not permanently.

3.4 **Phase Changes**: The feedback may lead to sudden jumps to another (relatively stable phase.

3.5 **Unpredictability**: The system is chaotically sensitive to its initial conditions

3.6 **Instability**: Over the long-term step changes or catastrophes occur.

3.7 **Learning Organization**: The organization evolves by learning from experience and errors.

The following is the state of the art interpretation by peer reviewed publications projecting these complex characteristics on the Construction Industry, a work that is in progress. Lucas's all 18 characteristics as grouped by Bertelsen (2005) (and adapted in this analysis) with the headings provided by Koskela (2000) and Shingo (1988) are then analyzed using as a background Richmond's seven skills for complex thinking, see attached Table 3.2. The matrix illustrates the intricacy of a full analysis of complex systems from a 'thinking' perspective. Although a written matrix depicts the theoretical fullness of an analysis, in practice these procedures are customarily performed, flexibly, to some degree. Complexity and flexibility are, according to Moses, the coin in the realm of systems that allows expending complexity dollars to achieve useful gains such as increased functionality, efficiency and or flexibility. For example, we now consider the three main groups identified by Bertelsen (2005): Autonomous Agents, Undefined Values and Non-linearity as they apply to building construction, using a systems thinking approach.

The purpose of Table 3.2 is to identify the matrix of complexity at this point in time that could be used in future research to filter the elements that influence the industry and thus become the vectors that affect the construction industry. From this matrix we adapt Bertelsen's (2005) Autonomous Agents, Undefined Values and Non Linearity and analyze them with the seven layered thinking process as an example of what can be done with the others.

Table 3.3 is more complex. If to this table we add a third dimension (say perpendicular to the sheet), the 'element of influence', we then have a three-dimensional matrix for analyzing the 'elements of influence.' This three dimensional vectorial calculus is identified in Chapter 6 as part of future work and will be further explained on how this work ties in with our understanding of vectors in Chapter 5.

Table 3.2 Complex Systems Thinking Matrix	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Koskela: Transformation Shingo: Operations	Dynamic thinking	Closed-loop thinking	Generic thinking	Structural thinking	Operational thinking	Continuum thinking	Scientific thinking
1.1 **Autonomous Agents**	**A1.1**	**B1.1**	**C1.1**	**D1.1**	**E1.1**	**F1.1**	**G1.1**
1.2 Non Standard	A1.2	B1.2	C1.2	D1.2	E1.2	F1.2	G1.2
1.3 Co-Evolution	A1.3	B1.3	C1.3	D1.3	E1.3	F1.3	G1.3
1.4 Self-Modification	A1.4	B1.4	C1.4	D1.4	E1.4	F1.4	G1.4
1.5 Downward causation	A1.5	B1.5	C1.5	D1.5	E1.5	F1.5	G1.5
1.6 Self-reproduction	A1.6	B1.6	C1.6	D1.6	E1.6	F1.6	G1.6
1.7 Mutability	A1.7	B1.7	C1.7	D1.7	E1.7	F1.7	G1.7
1.8 Fuzzy Functions	A1.8	B1.8	C1.8	D1.8	E1.8	F1.8	G1.8
Koskela & Shingo: Value							
2.1 **Undefined Values**	**A2.1**	**B2.1**	**C2.1**	**D2.1**	**E2.1**	**F2.1**	**G2.1**
2.2 Fitness	A2.2	B2.2	C2.2	D2.2	E2.2	F2.2	G2.2
2.3 Non-Uniform	A2.3	B2.3	C2.3	D2.3	E2.3	F2.3	G2.3
Koskela: Flow Shingo: Process							
3.1 **Non-Linearity**	**A3.1**	**B3.1**	**C3.1**	**D3.1**	**E3.1**	**F3.1**	**G3.1**
3.2 Emergence	A3.2	B3.2	C3.2	D3.2	E3.2	F3.2	G3.2
3.3 Attractors	A3.3	B3.3	C3.3	D3.3	E3.3	F3.3	G3.3
3.4 Phase Changes	A3.4	B3.4	C3.4	D3.4	E3.4	F3.4	G3.4
3.5 Unpredictability	A3.5	B3.5	C3.5	D3.5	E3.5	F3.5	G3.5
3.6 Instability (variability)	A3.6	B3.6	C3.6	D3.6	E3.6	F3.6	G3.6
3.7 Learning Organization	A3.7	B3.7	C3.7	D3.7	E3.7	F3.7	G3.7

3.3.1.1 Autonomous Agents

Complex systems, such as in building construction, are composed of independent or autonomous agents that are not identical. No permanent executive or directing node exists by design in the system with a control structure or leadership that emerges through self-organization. This self-organization (Kaufman, 1993) evolves and acts as an emergent control structure for the product and the process (Abdelhamid, 2004). These characteristics highlight the non-linearity, learning organization, self-organization, and downward process causation, with high variability and therefore unpredictability.

The autonomous agent's element is found between levels of the schema (such as sub-contractors, systems components, construction services, design services etc…) as well as within each level (i.e. Construction services). For example, in construction services, one autonomous group (the formal control structure) plans the project with a management-as-planning-and-dispatch modality and another autonomous group (the informal-control-structure) builds the project where self-modification, a learning organization, dealing with unpredictability and variability establishes a non-uniform variation from the formal control structure (Koskela and Howell 2002).

A design is a unique for the one-of-a-kind, on-site project created by a team assembled for the task (varying from project to project) which necessitates a co-evolution of (a) the process, (b) the organization and (c) the project that is unique to the project. This co-evolution of elements aims to fit the created 'fitness landscape' and achieve the 'local maxima' (terms explained in the next section) while keeping in mind the global maximum that has been (sometimes) established (to varying degrees) but that can change during the project gestation.

New materials, methods, design solution, processes and others require the ability of self-modification and a learning organization.

3.3.1.2 Undefined Values

The boundary of a system in the building construction arena is not initially specified and evolves in a dynamic communication to fit a landscape that, itself, is emerging. The concept of fitness landscape in this sense reflects the finding of the "local optima" high ground, for each part of the project, the process and the organization (be it design or construction or both). This is advanced through mutations in regards to an established (directly, indirectly or implied) relative global optimum in a balancing act between quality, cost and time as well as efficiency and effectiveness. However, this process does not occur at one level but at multi-levels in the schema creating a matrix environment of negotiations with no global optimum possible, a major characteristic of a complex system and thus a wicked problem.

The undefined value alludes to the non-standard and non-uniform one-of-a-kind product and process with a varying team that happens in space and time. The freedom of association or movement permits the clumping and de-clumping over time as the self-organization structures itself, the process as well as the product. This dynamic freedom aims towards the goal of creating value, albeit undefined, as we shall see. This value, exists even in a project that ends up in court, as it generate value for the litigation system at the expense of other stakeholders.

Every project establishes (explicitly or implicitly and to varying degrees) its own economic fitness landscape, quality fitness landscape, performance fitness landscape, cost fitness landscape, etc during the initial design stage[105]. "It is the nature of the project that it exists in its own fitness landscape" states Bertelsen (2005). This fitness landscape includes from the organizational side the design and production (construction) components in differing possible combinations called Project Delivery Systems. However, the fitness landscape is emergent with the building construction sector, the industrial sector, the general economy and social system to name a few upstream as well as downstream with sub-contractors and vendors. Each possible combination eventually affects the project local optima in a part, component of phase as well as the project global optimum. Therefore the local optima due to the aforementioned unpredictability, attractors, phase changes and variability (instability) create a local optima and global optimum much lower than expectations.

Unpredictable local optima has been the major complaint (Fisher 1993, Gann 1996, Johnson 1995, Winch 2003) when comparing building construction with other sectors such as manufacturing where aircraft (Barber et al. 1998; Voodijk and Vrijhoef 2003), ships and large complex systems reside but with differing parameters, and control structures. The drive behind the move towards a manufacturing based construction industry is a desire for increased efficiencies, i.e. reducing initial cost or labor, like in other industries (Latham 1994, 1988; Egan 1998, 2002). In their opinion, the construction industry is fragmented, a flaw to be remedied (Gann, 1996; Pike 2002; Woudhuysen and Abley 2004). However Dickson (2003) views that the industry outputs and outcomes are what is important; that valuing in addition to costing is important and that a diverse, open, and flexible industry should be celebrated. The key in these contrasting positions is that manufacturing, as it is presently configured is for mass production and this introduces a rigidity and inflexibility that runs contrary to the design and construction industry in its current configuration.

[105] "Fitness landscape" in this sense can be considered as a term that encompasses, among others, the concepts underlying 'building performance indicators.'

Bertelsen (2005) observes, and we concur, that there "does not exist an absolute optimum" for a project, thus the "best solution" is dependent on the system's real-world status. Others may counter that although relative in time, with the state of the art, a performance based building design coupled with a total building commissioning plan (NIBS 1999), can establish a "relative best solution" or "relative optimum" that can serve as a project goal (Altwies 2001). However, it is precisely problems without absolute optimal solutions that are wicked problems since the pre-conditions change as the solution evolves.

The project represents an emerging physical structure, and emerging process, through an emerging organization in time and space with increasing order and purpose and the intent of generating a specific value. This value, although constructed in the narrow sense for the client, ends up being a value for all the levels of the general schema and thus the longevity and open structure of the industry where variability is a key complexity characteristic.

3.3.1.3 Non-Linearity

Complex systems are non-linear. Their outputs are not proportional to their inputs; the whole is different from the sum of its parts. A roof is just a roof; a house without a roof has much lesser value, if any in some cases, than a house with a roof with much higher value than the first one.

The project itself acts as a dynamic attractor for an emerging organization of otherwise disparate stakeholders, autonomous agents with alliance to their parent organization. However the temporary project organization for a space and time self-organizes in formal and informal structures as a service, production and process system. The project dynamic contains multiple and sometimes conflicting attractions creating a matrix of possible and different behaviors within the project duration and between projects by the "varying team" factor. Within the project "partnering" is an attempt to bring in line the sometimes-conflicting attractions (see Black et al.

2000 for success factors and benefits).

The initial configuration of the team is in constant flux, thus, a multitude of actors create the system history that coupled with phase changes and milestones where transitions occur not only place the project at the 'edge of chaos' but is also a difficult history to capture fully for lessons learned exercises that would benefit a learning organization. These transitions are critical points in connectivity requiring the system (project, process and organization) to self-modify, self-organize and co-evolve to manage the fitness landscape, local optima and global optimum. The project organization limited time existence, does not allow it to emerge to a higher plateau, even if it is an intermediary step from the next full level of meta-organization, virtual organization, integrated organization that is found in Heavy Industry, such as Petro-Chemical and others.

In heavy industry, such as in a refinery, the high risk level and complexity require a smaller team that is relatively constant due to long project durations and teams moving from one project to the next seamlessly; Where one-of-a-kind solutions are discouraged, lessons learned are fully captured (or catastrophes induce heavy insurance premiums that become a motivator to capture lessons learned and apply them through standards, regulatory framework and codes).

In buildings, understood as an assembly of systems (a system of systems), the wicked nature of the design as well as the construction processes and the client itself as a complex system (Bertelsen and Emmitt 2005; Emmitt 2003; Pries et al. 2004) makes it possible and most probable that small differences between stakeholders will lead to vastly different solutions, different processes and different project organizations. In other words, chaotic sensitivity to initial conditions makes a project rich in unforeseen events, deviation from plans and variability, thus affirming the concept of contextuality of a complex system.

The most critical decisions by the stakeholders are affected by the disposition or attitude towards what eventually becomes the project driving principle: cost, value or quality which changes throughout the project phases and duration beyond the initial construction, its life cycle. The expressed, implied or inferred attitude by the stakeholders, individually and collectively introduces sensitivity to chaos that is magnified through the project. The non-linearity of the project carries through the non-linearity of the building construction sub-sector, the non-linearity of the industry and the general economy. These additional levels of non-linearity upstream and downstream create a complex dynamic mechanism that is almost impossible to study in holistic or particular detail.

Lastly, building construction is nested in a social system with a varying team where communications and cooperation are emergent phenomena in each project. Cooperation is based on the project attractor for common behavior sometimes based on experience and performance but oftentimes based on low bid. Common behavior stabilized the project cooperation (Bertelsen 2005) "in either a good or bad way" creating the 'project culture'. This culture, however, reflects all the characteristics and attributes of the larger social culture that includes cooperation, fighting or fleeing behavior along with a myriad of other social types of behavior. Thus culture adds another dimension of unpredictability with a number of entrants and departures disturbing the 'project culture' stability in completely unforeseen ways.

This analysis of complexity in building construction does not pretend to be exhaustive. However it illustrates how the project, process, emergent organization, culture, and the other mentioned characteristics of complexity such as autonomous agents, undefined value and non-linearity are intertwined. We postulate that the dichotomy of project / process in building construction is so blurred that it may be theorized that a building is a project whose emergent and intrinsic quality is that of a process where the project, along with organization and all the supporting networks of services and products form the fundamental elements of the process. In Palmer's (2003, 2004) terminology it is a meta-system formed by a paradox with two axes, project and process and everything that comes within the boundary of that paradox will inherit the intrinsic paradoxical qualities. The project defines existence, while the process defines movement if a differentiation needs to be made, although in reality they are one because they are mutually co-dependent, a characteristic of the paradox in meta-thinking.

3.3.2 How has ToC elevated the thinking towards the dissertation goals?

One of the identified threats to the logic behind this dissertation was the concept of building construction being like manufacturing and other self-contained industries such as aircraft, shipbuilding and automobile. If this is the case, then a different worldview, that of systems, is applicable, and we should be able to manage and control the industry in response to the threats. A manufacturing process has levels of efficiency, risk control, effectiveness, that allows complexity to be manageable and studied scientifically. Change in that environment is controllable. However if building construction is not like manufacturing and other more self-contained industries, then we need to find out a worldview that allows us to understand it, such as that of meta-systems, industry of industries with its characteristics and peculiarities, albeit being a theory in progress. Such proposed theories has potential for interpreting and understanding building construction, accepting the peculiarities and characteristics and for the purpose of this dissertation identify how complex systems change in this meta-systemic environment.

The ToC analysis and the survey of the literature surrounding the subject of building construction regarding manufacturing has helped dispel the notion of a close and direct relation between building construction and manufacturing. To do this we had to differentiate product and process in both camps, and deeply search, (according to the state of the art of scientific and heuristic research in the areas) an understanding and implications of complexity in the industry. This work gives us confidence to proclaim an affinity in complexities between the meta-system found in building construction and those in the Industrial Revolution rather than building construction and manufacturing, for example. If the elements that have influence the Industrial Revolution and those that influence change in building construction are akin, then through the worldview of meta-systems we are on track to treat this with heuristics rather than with more precise scientific tools, at this level of understanding where we are in a pre-paradigm mode. In other words, this is the state of the art of this nascent understanding of complexity regarding very pressing questions that sustainability has raised when faced with exponentialoid growth.

3.4 CRITERIA FOR DRAWING THE BOUNDARIES TO CAPTURE THE NECESSARY AND SUFFICIENT ELEMENTS OF INFLUENCE (GENERATORS OF COMPLEXITY)

The following criterion launches the methodology of this dissertation that portends to develop a new approach for analyzing complex systems. Five general features are identified from the *aims* of a Theory of Complexity to inform the ultimate workings of a system that analyzes complexity in any field and thus in Building Construction:

1. **Prediction**: The search for predictive algorithms in nature that displays common features across many levels of disparate organizations. Complex situations are often soft and incorporate value systems that are abundant, different, and extremely difficult to observe or measure thus may be better-represented using nominal and interval scales.
2. **Control**: Awareness that delays to negative feedback loops increases the tendency for the system to oscillate, to become paradoxical or have paradoxical oscillations. Oscillation and instability reduce the ability to control for confounding variables and be able to discern cause and effect.
3. **Explanation**: A theoretical understanding and/or explanatory description of a system / framework for a number of phenomena; Insights into the phenomena with natural language might be the main approach at uncovering knowledge.
4. **Aspiration for universality**: Applicable to a wide range of diverse phenomena; Not

necessarily linked to the discovery of a unifying theory.

5. **Unifying theory**: The coherent subject matter of complex systems science and the right level of abstractions at which its mechanisms and processes can be given a unified description.

Furthermore, the elements of influence must exhibit the following characteristics:

1. **Radical openness**: A feature internal to the ambiance.
2. **Contextuality**: Senge (1994): (i) when the same action has dramatically different effects in the short run and the long; (ii) when an action has one set of consequences locally and a different set of consequences in another part of the system or the meta-system or the ambiance; (iii) when obvious interventions produce non-obvious consequences.
3. **Internal homogeneity**: Structural differentiation, increasing distinguishing non-trivial characteristics; Simon (1962): Depends on whether the metaphors capture the real world and are significant or superficial.
4. **Adaptability**: A system in disequilibrium and evolving; Self-modification in response to external forces (concepts of feedback and homeostasis) evolving over time, that is, involve changing internal structure, changing external relationships to other systems, change with the ambiance or and changed by the ambiance, differential growth.
5. **Non-linearity**: No single optimum, too many variables. The past cannot be compared well to the current circumstances. Unfamiliar or unintended feedback loops exits; Many control parameters with potential interactions; indirect or inferential internal and external forces.
6. **Net like causality**: The web of interconnections among disciplines, domains, and systems; the existence of multiple interacting feedback means it is difficult to hold other aspects of the system constant to isolate the effect of the variable of interest (many variables simultaneously change, confounding the interpretations). A number of natural systems characterized by not only an intricate internal dynamics, but that also have the potential to interact with neighboring systems to the extent that it transforms and is transformed by them.

3.5 CONCLUSIONS

In this chapter, we analyzed observed past and current studies as point of departure for an inquiry into the nature of systems that could help describe the construction industry. Specifically we have analyzed the studies of Forrester and Sterman to establish that these reliable studies fail to convince whether the required reductions in ecological impact can be realized to tame the observed exponentialoid growth rates.

We focused on the state of the art knowledge on ‘complexity’ because this is the key to understand the boundaries of the systemic nature of building construction and the characteristics that we need to anticipate in our argument regarding how the elements of influence, to be discovered in Chapter 4 affect an exponentialoid. In other words, chapter 3 establishes what we need to be looking for in order to better understand ‘complexity’, specifically ‘complexity in the systemic nature of the building construction industry’ and ‘complexity in the elements that influence change in the systemic nature of the building construction industry’s Russian doll approach. What we have found in this study is that current science models are mostly algorithmic in nature. We are taking care to build a world view that takes account of complexity instead of reducing complexity to formulas dependent on assumptions.

CHAPTER 4

A WORLDVIEW OF THE INDUSTRY BASED ON HISTORICAL THINKING

In this Chapter we are going to address the issue of change through (i) population change; (ii) the building industry (1700 – present) through historical thinking, the analysis of the evolution of Industrial Revolution (IR)[106] in Western Europe; and (iii) building construction through the surrogates of the high-rise, the air conditioning and the elevator.

We are identifying the elements that influence change by analyzing expert's interpretation of population and the evolution of the IR in Western Europe. The elements that influenced change are embedded in their history.[107] The link between IR and population growth is well researched although there is some controversy on what caused the IR to bloom first in the UK (Landes 2003; King and Timmins 2001).

The same reasons apply to why we have selected the high-rise building, air-condition and the elevator. In chapter 1, we addressed the reasons for selecting the high-rise building and not hotels, sewer treatment plants or bridges and why we have limited this search to one building type and not housing or other building types. In summary, these chosen surrogates are selected because of time constraints and availability of credible publications. Other surrogates should yield a list of the same elements that influenced change using the same methodology. Further

[106] (NOTE: Different historians have used different typological characterizations for addressing the evolution of the events leading to and of the 'several' Industrial Revolution (IR). Some have it as pre-IR, IR and Post IR other by sectors such as Agrarian Revolution, Industrial Revolution, etc. We have chosen the division stipulated by Landes[106] (1969 and 2003): The First Industrial Revolution 1700 – 1850; The Second Industrial Revolution (1850 – 1940) and the Third Industrial Revolution 1940 – 2000. To this we have added the Fourth Industrial Revolution 2000 – Present. The reasons for this decision will be addressed in greater detail in this chapter.

[107] China has experienced, during this time, an exponential population growth and a Cultural-Political Revolution with agrarian and health improvements. Issues of China population numbers and demographics were addressed in Chapter 2. Friedman (2005) observes that China and India have, in a sense, bypassed the I, II and III IR and have leapfrogged into the IV using technologies developed elsewhere.

study can apply the methodology proposed in this dissertation to other building types and subsystems as a form of validation of the findings in this dissertation.

We are going to focus on the following question: Can we determine through the analysis of the (i) population change and (ii) the evolution of the IR the major elements that have influenced the changes encapsulated in this period of time? To extract the major elements that influence population change, we relied on Malthus (1983) and his critics. We applied Causal Loop Analysis (CLA) techniques to the stories of the IR, the high-rise, air conditioning and the elevator to extract the elements that have influenced change. In Chapter 1, under methodology, we addressed the reason for choosing CLA.

What we have found is that regarding (i) population growth there was a natural sustainability, a dynamic period where natural sustainability was progressively negated and a period where not only is natural sustainability negated but the opposite, human intervention in favor of the species created the climate for an exponentialoid growth. Regarding (ii) the evolution of the IR, the elements of influence during the different IR can be also discerned and tracked. This tracking is made through a system using positives (status quo maintained) to negatives (change in status quo), a convention explained in greater detail in this chapter. For right now, this convention was used in Malthusian Positive Checks that takes (according to its given name) the environment and its natural sustainability as positive and changes to the natural sustainability through human intervention as negative. The convention is counter-intuitive but we rather keep it than create a new convention by performing surgical anachronism or historical revisionism.

We also found that (iii) analyzing the history and evolution of the high-rise building, air conditioning and the elevator we can identify the major elements that have influenced change.

The implication, for the next step in our argument, is that these elements themselves (although complex) showcase vectorial components, (containing value and direction) a concept elaborated in Chapter 5.

The worldview we are interested in creating is only one particular aspect of an 'elusive, complete' worldview. Our worldview is interested with building construction and its boundaries, complexities, and relations with other worldviews. One in which building construction is not reduced by simplification but encompass its found characteristics which include complexity, as understood by the heuristics, the state of the art of knowledge at this point in time. A worldview informs the schemas we use to characterize the particular area of interest, building construction, and how it relates, the mechanisms and forces that affect change, and in our case how they address the exponentialoid issues. As mentioned, we create this world view by searching philosophical foundations using the tools of metaphysics, epistemology and ontology, the work of chapter 3. Furthermore, our worldview, by the nature of the problems raised, encompasses the boundaries between the natural and the artificial environments.

4.1 SUSPECTED ELEMENTS THAT INFLUENCE CHANGE

Buildings are created to satisfy human needs and wants, which relate directly to multiple population issues (such as population numbers and the demographics of those numbers). Population numbers have metrics, albeit at a macro level, using statistics and probability, which can be used in our conceptual model of systems relations. Demographic changes are more elusive metrics, since up to the present, demographers have used a relative constant of 20% of the population as 'developed' (using 80% of resources) and 80% as 'developing' (using 20% of resources – also known as the Pareto Law or the 80/20 rule). This understanding has changed recently, as we shall examine.

For the purpose of this study, these numbers are a face value benchmark, such as the number of population per dwellings (6 persons per dwelling global – Davis 1999) with multiple attributes, such as culture, society and economy among others. (In the USA the number is more like 1.9 persons per dwelling.) The number of housing units (immobiles[108]) required to meet a population density[109] requirement are related to population numbers, and a change in living standards directly affects the type of the housing unit, according to cultural norms and traditions. These metrics are then related to per capita consumption, such as the amount of energy consumed and emissions generated by the living standards (i.e. developing and developed). We limit our comparative effort to commodity consumption, namely selected mineral resources used by building construction industry.

For example, in *Fig. 4.1 Conceptual Model of Systems' Relations*, literature search indicates a widely held estimate that 80% of the population consumes 20% of the resources (developing), while 20% of the population consumes 80% of the resources (developed). However since approximately the 1950's a new demographic change has taken place where a relatively significant portion of the developing population has migrated from developing to developed consumption status. This shift was estimated in 2000 to be approximately a 5% yearly migration; however recent estimates indicate that the migrating percentage is approaching 10% (Raven and Berg 2004). Furthermore, literature search indicates that 40% current emissions generation comes from the life-cycle of buildings and the rest, 40% comes from

[108] European real estate uses the reference of immobiles (that is permanent, not movable) to contrast with other type of industries and assets where the final product is mobile - that is of impermanent location.

[109] Density is affected by external and internal environmental factors that are beyond the scope of this study such as detailed characteristics of birth rate, death rate, migration or dispersal (immigration and emigration) and other forces such as environmental resistance and carrying capacity *(K)*. Interestingly, the main unknown factor of any scenario is Earth Carrying capacity which according to Dr. Joel Cohen (Raven and Berg 2004) is widely dependent on assumptions made about: standards of living, resource consumption, technological innovations and waste generation.

transportation and 20% from all other sources (artificial such as transportation and natural such as volcanic activity) (Raven and Berg 2004).

The characteristics of population dynamics and demographic is different from the characteristics of increased resources demand and emissions generation. Based on this conceptual model, in our pilot study of the air conditioning, we identified a preliminary list of elements that influence change in building construction.

In this chapter we address the most important question: How do we know that this list comprises the necessary and sufficient elements of influence? The proposed method,

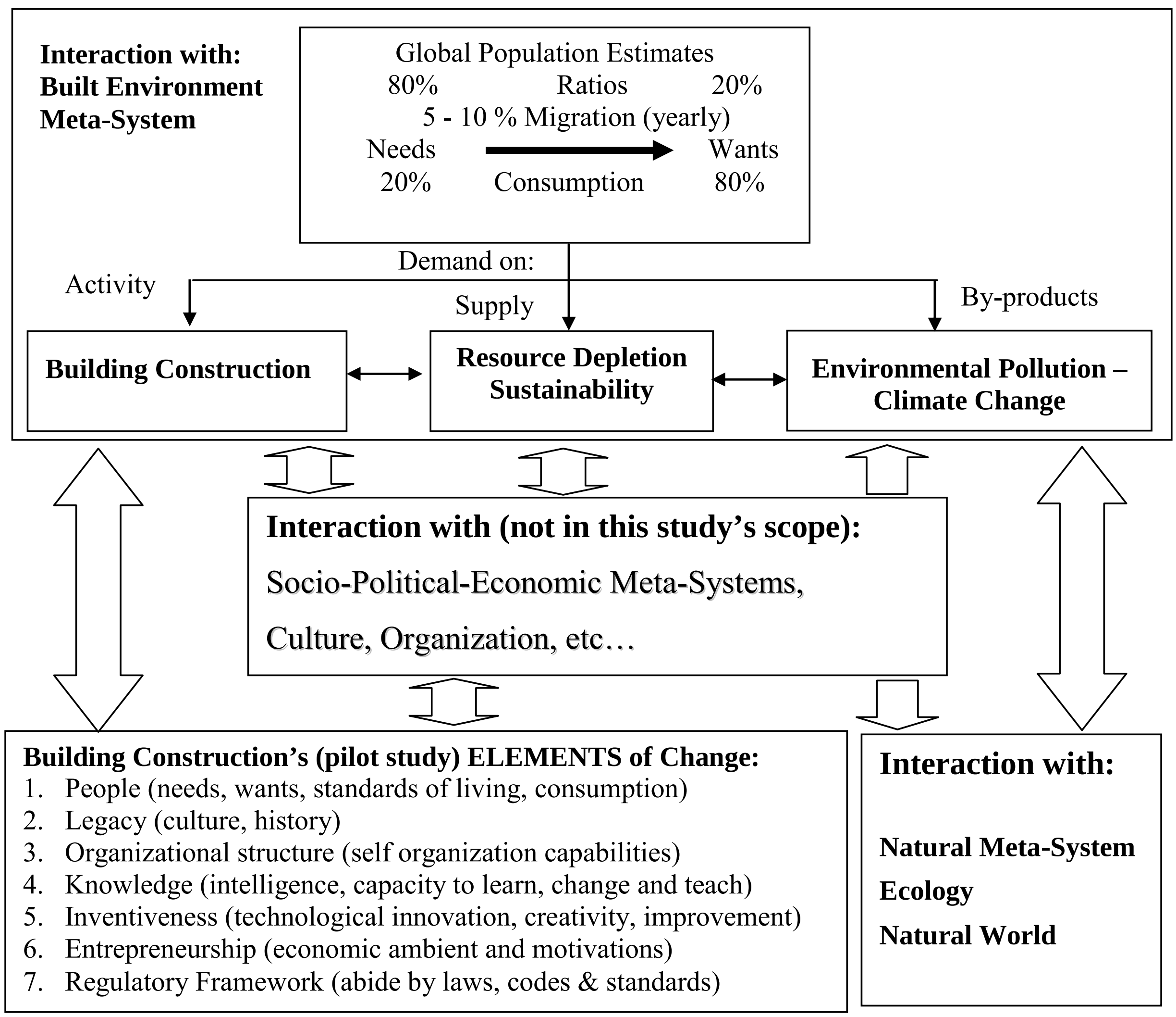


Fig. 4.1 Conceptual Model of Systems Relations

recapitulating the above summary uses (i) elements that influence population change to give us a method of analysis, (ii) the elements of influence of the industrial revolution point towards the elements that have influenced the industry, and (iii) elements of influence of the high-rise, the air conditioning and elevators yields the elements that influence change in building construction.

4.1.1 Historical search for BC industry's elements of influence

Building construction is a sector of the General Economy[110]. The General Economy is embedded in the timeline of historical events. One of these historical events, what we now call the Industrial Revolution, is very well documented and has exerted significant and lasting influence on building construction.

The links between the Industrial Revolution (IR) and Building Construction (BC) of the era allows the transference of descriptors and parameters with internal coherence. This internal coherence is strengthened because both the IR and BC exhibit meta-systemic characteristics, and affect and are affected by population characteristics.

We search this historical period using the tools of historical hermeneutics in an attempt to reach out for sympathetic understanding via the humanities discipline for a worldview or a frame upon which we can then apply quantitative or vectorial analysis. Again, the objective of this search, at this time, is that of meaning rather than quantity such as the identification of the elements of influence active during this period. The purpose for identifying these elements of influence is to create a worldview of the drivers of change.

[110] Under the NAICS (North American Industry Classification System), the construction industry is listed in the service sector of the economy under section 23 and is broken down into many categories, such as Buildings (236) and Heavy and Civil (237). Construction is considered a basic industry like others such as manufacturing, mining, fishing and farming (www.census.gov).

The Industrial Revolution in Western Europe is a deep transformation of several industries, thus it is multi-discipline (sectors) and Landes (2003) has identified three peculiar evolutionary phases: the First (ca. 1700 – 1850), Second (1850 – 1940) and Third (1940 – 2000) Industrial Revolutions. Within this period some authors use different typological characterizations of the 'several' Industrial Revolutions and identify the revolutions under other names. Other authors' typological characterization indicate their area of focus, such as the Agricultural Revolution (with the advent of organic chemistry, pesticides, herbicides etc) or the Information Revolution (with the advent of electronics, computers, fiber optics, Local Area Networks, robotics, etc). Furthermore, others identify revolutions in different areas such as *organization, technology, economy, education, government and social attitudes*.

This study is concerned with identifying the elements that influence change in the three phases of the Industrial Revolution mainly from three different cultural, economic and social perspectives, (British[111], French and German[112]) since each country acted and reacted to the industrial revolution differently. Western Europe is the focus of the First IR because other continents during this period of time remained relatively stable and reacted later to the IR, although North America did eventually catch up during the Second IR.

4.2 A BUILDING CONSTRUCTION WORLDVIEW

A detailed analysis of the historical elements that influence change affected population, provide the foundation for the characterization in *Fig. 4.2* that schematically links building and infrastructure demand, resource consumption, emissions, the environment (becoming more dynamic), climate change that creates further building demand.

The demand from catastrophes on building construction is two fold: First there is the

[111] Britain is also referred as England, Great Britain, or United Kingdom (U.K.).

first respondent demand for immediate temporary shelter, followed by the construction of permanent shelter and other buildings.

The population graph, when analyzed using Malthus and his critics, can be characterized by four phases. The population graph is a time-line embedding historical events on the 'x' axis and population number in the 'y' axis. The time-line then is more than time, it is also encompasses human history. Phase I displays a continuous gradual slope in population increase that corresponds to the living conditions of each period with their gradual advances and setbacks. Phase II displays a significant population increase attributed to improved overall living conditions after the major setback of the bubonic plague, that as a major catastrophe, scholars attribute to it major structural changes in society. Phase III continues population growth but at an exponential rate, due to impressive advances based on the previous phase significant societal structural changes. Phase IV projects into the future the current growth path towards infinity, which scholars deem unsustainable or is moderated by forces at work within society, which is the exponentialoid, is tamed.

[112] Germany is also referred as Prussia.

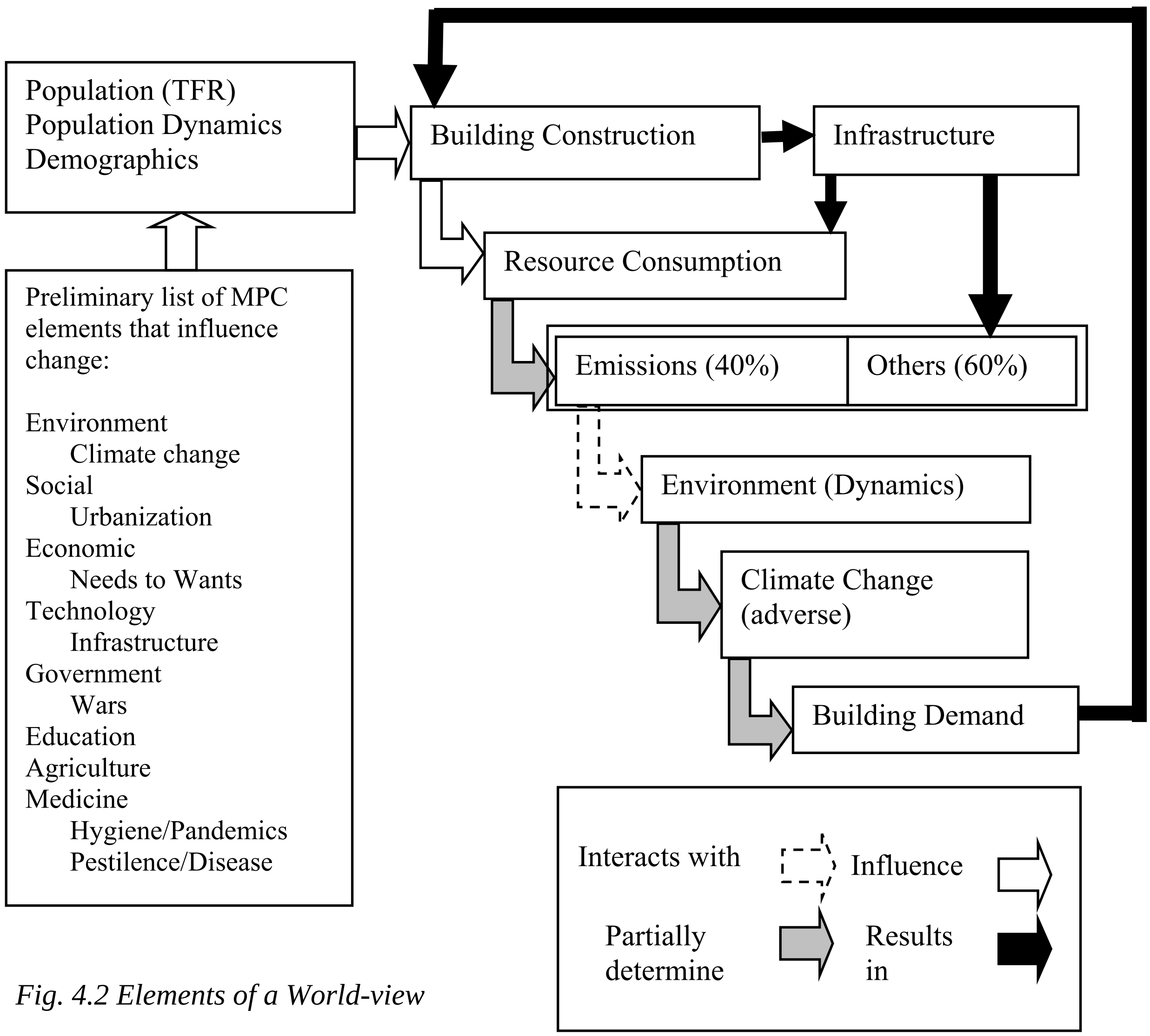


Fig. 4.2 Elements of a World-view

Malthusian Positive Checks (MPC) infers that natural sustainability suppressive forces on population increase (see MPC Phase I in Fig. 4.3) were eventually negated by human advances in science and technology (MPC Phase II). Human advances in all fronts of knowledge created a dynamic condition allowing the Total Fertility Rate manifest its exponentialoid at the time of the Industrial Revolution (MPC Phases II and III). García Bacca (1989) introduced the exponentialoid concept that was discussed in Chapter 2 and will be elaborated in the following sections.

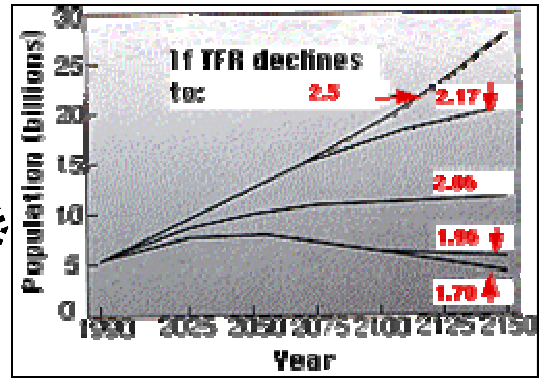
In MPC Phase IV we see the effects of artificial sustainability, i.e. medical and cultural methods; the education and voting rights of women; the migration to urban environments, the concerted effort of governments to limit population growth to one child, such as in China, increased affluence, and the influential forces of global communication (such as cross boundary national and cultural exchanges with satellite TV and radio) among others.

In the words of García Bacca and McHale, "the world has shrunk exponentially with the advent of technology." Human manipulation and control of these forces testify to the polarity of the elements of influence.

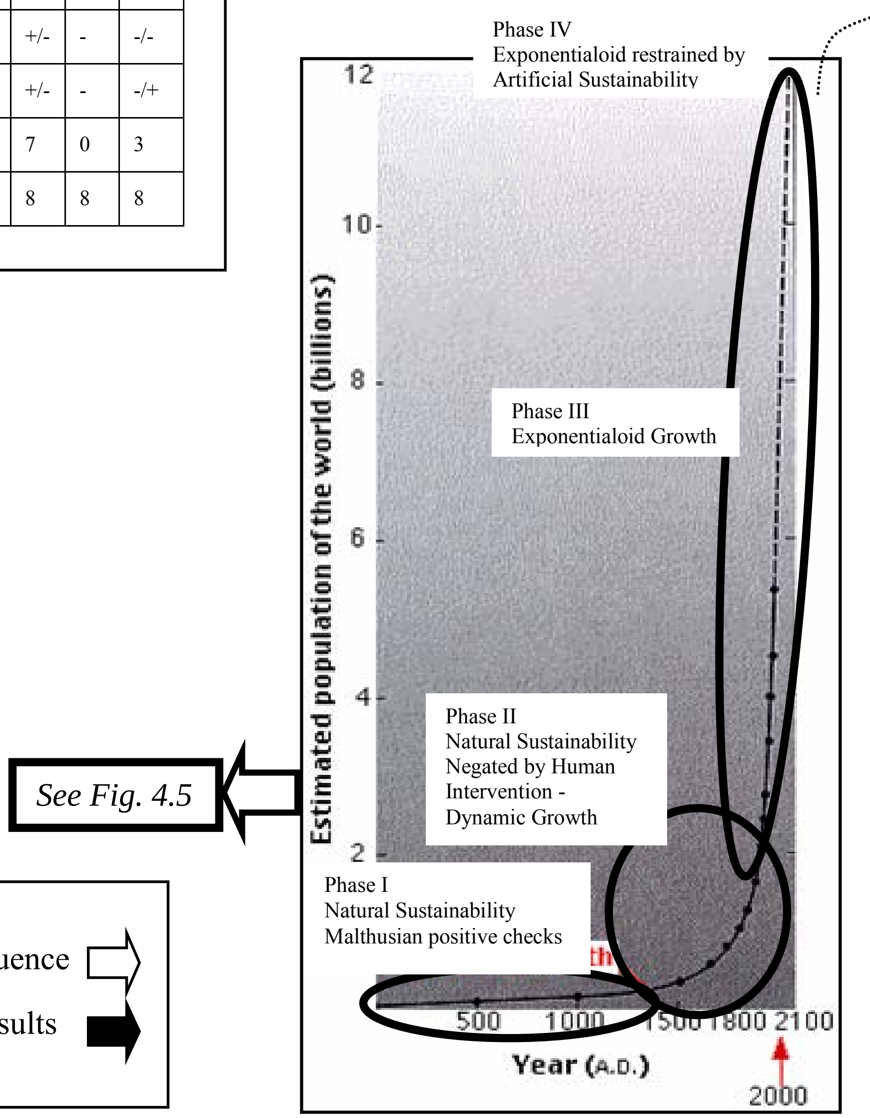
The elements identified through literature search based on the Malthusian Positive Checks are actors, in general. Each element is a collective so that the sum of the totals in each collective has an influence on the Total Fertility Rate. However one actor with its collective may not be sufficient to affect or alter the Total Fertility Rate such as in MPC Phase I, when Malthus (1983) theorized that high mortality ultimately kept a population increase in a relatively stable form.

Malthusian Positive Checks (MPC)

Influence/Phase	**I**	**II**	**III**	**IV**
Environment – Resource consumption/Climate change	+/-	-	-	-/+?
Social Urbanization	+	+/-	-	-/-
Economic Needs to Wants	+	+/-	-	-/-
Technology Infrastructure	N/A	+/-	-	-/-
Government Wars	+	+/-	-	-/+?
Education	+	+/-	-	-/-
Agriculture	+	+/-	-	-/-
Medicine - Hygiene/Disease/ Pandemics / Pestilence	+	+/-	-	-/+
+ Totals	7	7	0	3
- Totals	1	8	8	8



Predicting Population per TFR



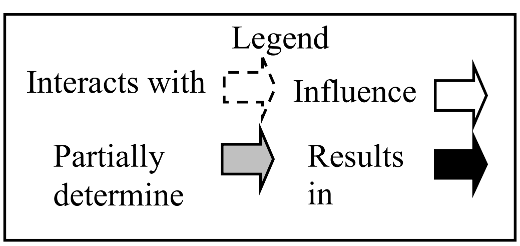


Fig. 4.3 World-view: Population dynamics and building demand

However, when a critical number of elements of influence coalesce in a force with a particular sense, direction and magnitude, the Total Fertility Rate is sufficiently changed or altered to result in a population growth change such as in MPC Phase II. MPC Phase II is indicative of a period with advances in medicine, agriculture, technology (more efficient and available energy sources: wood, carbon, coal, fossil fuel, gas; machinery, trains etc…), urban living, (food, work, sanitation and potable water, resources) and other actors (such as the advent of technology and sciences.) The potential within the Total Fertility Rate became dynamic (high birth rate with increasingly less mortality rate – i.e. longer life with more relative affluence by larger numbers of the population).

Population dynamics accelerated the exponentialoid growth evidenced in MPC Phase III. MPC Phase IV, likewise, has the same elements of influence moving towards a different position resulting in a decrease in the Total Fertility Rate, and an increase in life expectancy. The decrease in the Total Fertility Rate is currently being observed in many nations. Population decrease has paradoxical consequences, as we have seen in Chapter 2.

Population number is the measure, the Total Fertility Rate is multiplying factor, and the forces behind it are the elements of influence. A change in population number is achieved only through a change in the TFR through a change in the elements of influence sense, direction and magnitude. The elements of influence and the constituents of these elements appear to be vectorial. The elements of influence in population and the elements of change in the industry have the same characteristics.

This dissertation shows that the forces that affect the building construction industry are directly related with both population numbers and increasing affluence, (see *Fig.4.8.*) Therefore, building construction is directly affected by the elements of influence found through the

Malthusian Positive Checks (MPC).

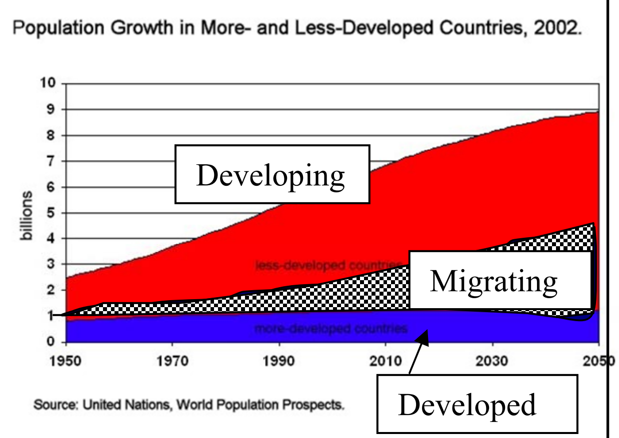
Population growth and demographic migration in affluence apparently is the primary force affecting the global economy in the twenty-first Century and, by default, building construction, resource consumption and emission generation.

Malthusian Positive Checks

Influence/Phase	I	II	III	IV
Environment – Resource consumption/Climate change	+/-	-	-	-/+?
Social Urbanization	+	+/-	-	-/-
Economic Needs to Wants	+	+/-	-	-/-
Technology Infrastructure	N/A	+/-	-	-/-
Government Wars	+	+/-	-	-/+?
Education	+	+/-	-	-/-
Agriculture	+	+/-	-	-/-
Medicine - Hygiene/Disease/ Pandemics / Pestilence	+	+/-	-	-/+
+ Totals	7	7	0	3
- Totals	1	8	8	8

Global Population Estimates
80% Ratios 20%
5 - 10 % Migration
Needs → Wants
20% Consumption 80%

Conceptual Model of Needs/Wants



Theoretical scenario of population demographics moving from needs to wants

See Fig. 4.5

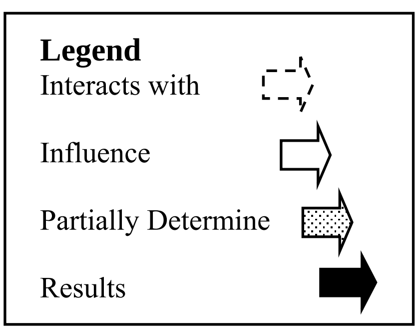


Fig. 4.4 World-view: Demographics and building demand

The consequences to building construction directly and indirectly through climate change are characterized in *Fig. 4.5*.

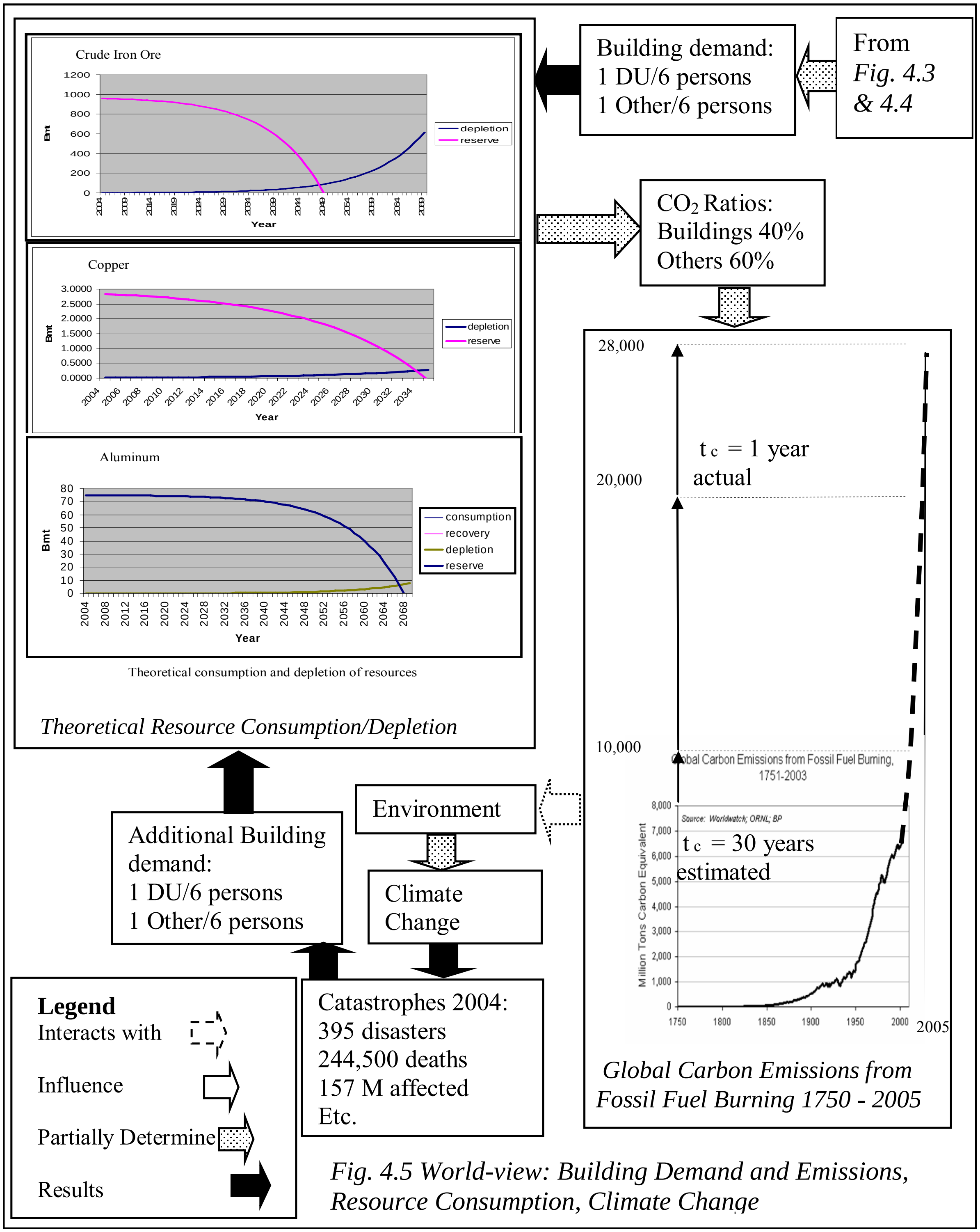


Fig. 4.5 World-view: Building Demand and Emissions, Resource Consumption, Climate Change

For example, current population estimates are at 6.5 Billion, if 20% consume 80% of resources the population estimated to be in this level of developed consumption is 1.3 Billion. However, if 10% of the developing population is migrating yearly to a developed level of consumption we have an additional 0.65 Billion (650 million) people, each year, placing demands on resources and producing emissions at the higher level (Kibert 2005). This estimate is a good approximation of reality.

Overall economic indicators of commodities used in construction, relatively stable otherwise, are increasing at an average rate of approximately 20% yearly which tend to corroborate a higher demand on resources. The projected estimate increase in population of 3 Billion by the year 2050 (Raven and Berg 2004) add to the developing pool of people, which affects the possible future migration from "developing to developed." Increase in affluence is attributed to global incentives by Governments, Non Government Organizations (NGO) such as charities, philanthropists, the United Nations, and globalization, education, technology that promote a decrease in mortality rates and an increase in affluence.

We now address the question of how does the building construction industry respond to these challenges? In order to answer this question we need a worldview that informs the relationships. *Fig. 4.6* proposes a characterization of these dynamics. In our pilot study of air conditioning we proposed a preliminary list of elements that influence change applicable to building construction. We have several tasks at hand: Where does this list of elements of industrial change come from? Does this list contain all the necessary and sufficient components? Are these elements of industrial change capable of meeting the challenges of population growth and demographic changes in affluence, resource consumption and emissions generations each exhibiting exponentialoid growth characteristics?

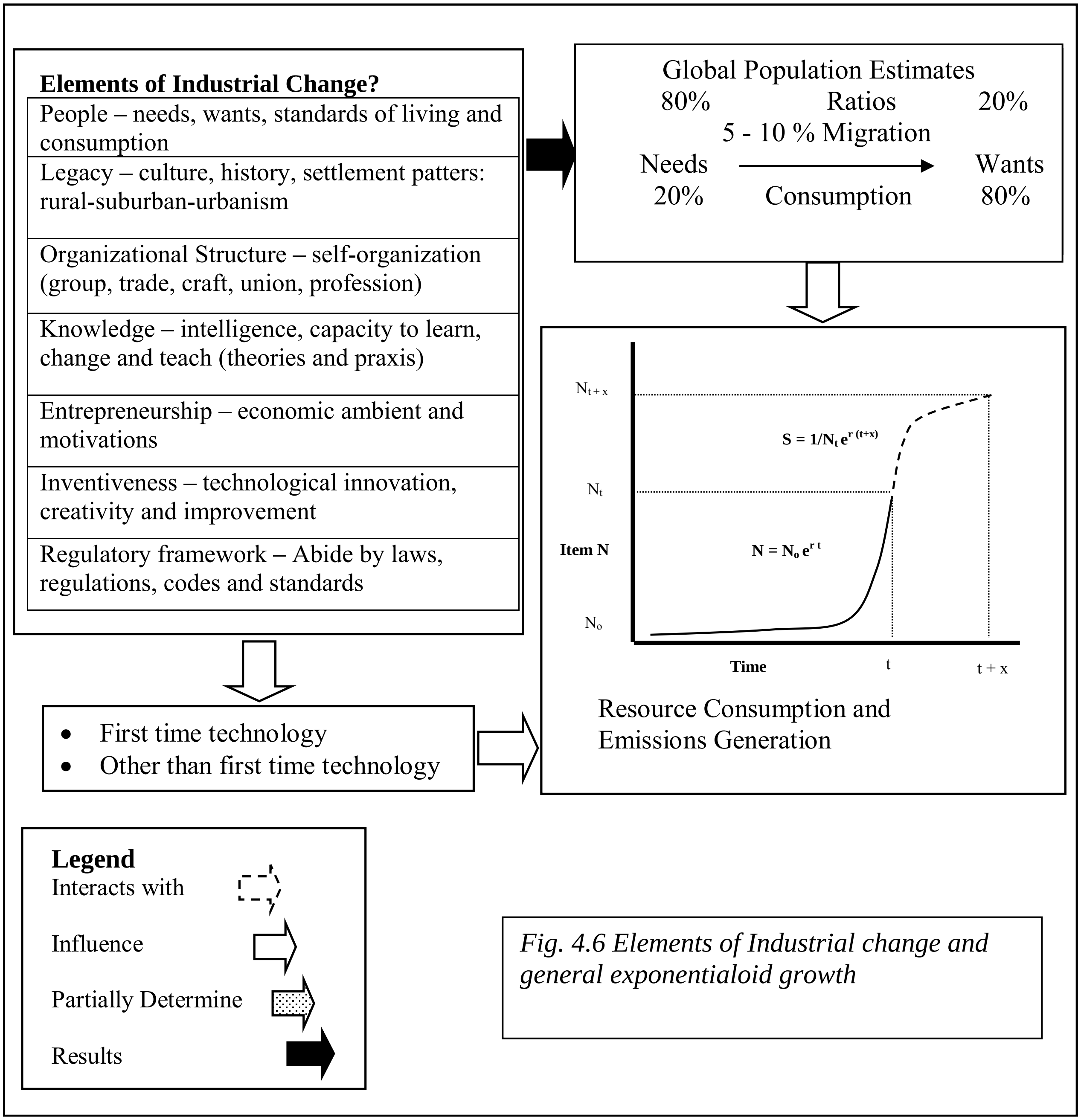


Fig. 4.6 Elements of Industrial change and general exponentialoid growth

4.3 ELEMENTS THAT HISTORICALLY HAVE ENGENDERED CHANGES IN THE INDUSTRY

In the previous section we analyzed the elements that influenced population change and how population change affects building construction. The purpose of this section is to define the elements that influence industrial change in general and in building construction as an industry in particular. The method used for this analysis is similar to the one used in the population analysis, therefore there is an apparent overlap. However, this sections purports to verify the

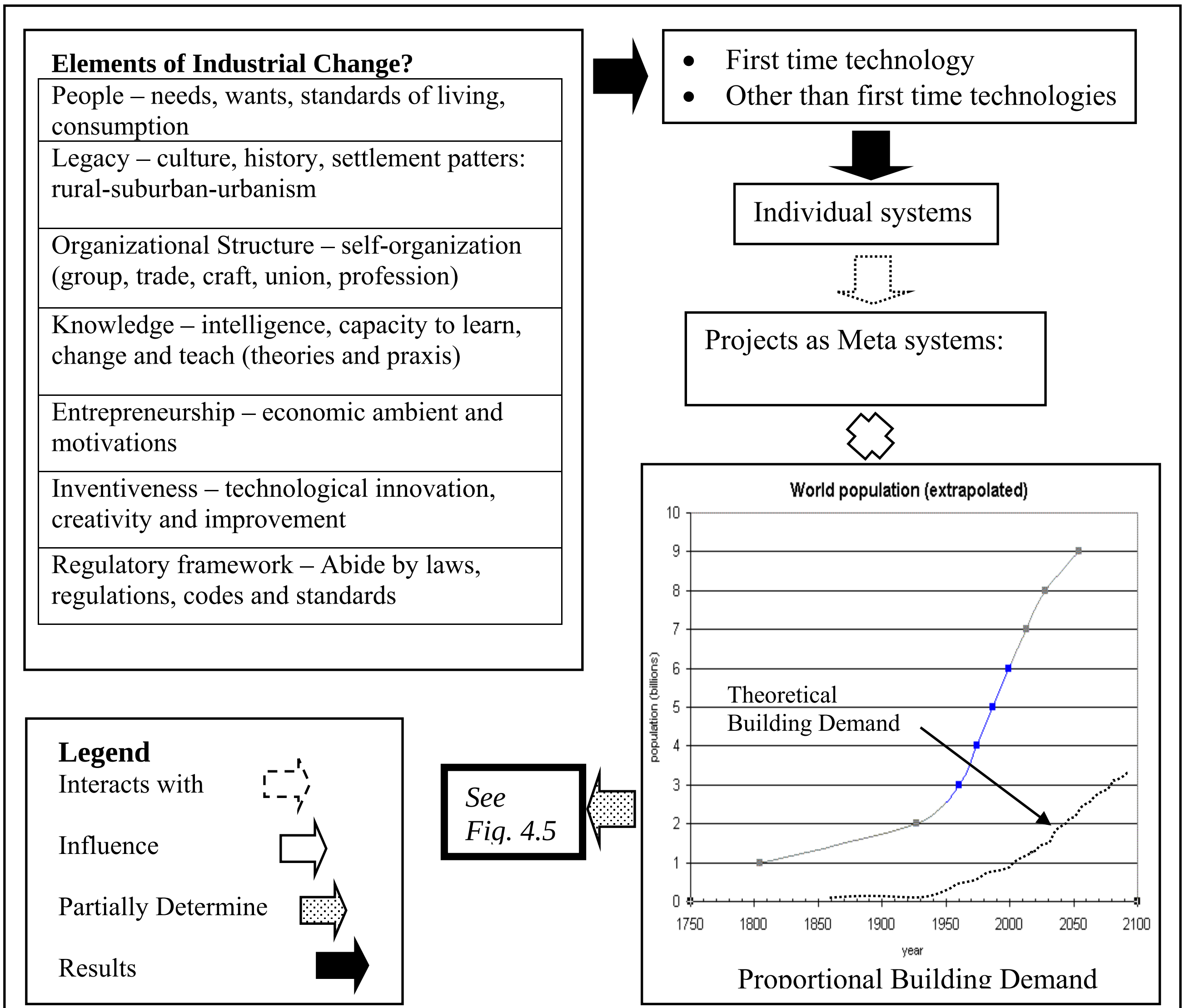


Fig. 4.7 Elements of Building Construction World-view

previous conclusions.

Our pilot study, using CLA on the evolution of the air conditioning, generated a preliminary list of elements for change in Table 4.1 and in *Figs. 4.6 and 4.7* that needs to be verified. In order to accomplish this verification of the elements of influence, we analyzed the Industrial Revolution from 1700 to the present. The work in this section is based on Appendices F, G, and H, abstracts of the IR.

The theoretical building demand in *Fig. 4.7* is heuristic, arrived by dividing the total population at a point in time by Davis (1999) estimated 6 persons per dwelling unit and 6 persons per other building types, a rough global estimate based on the state of the art knowledge at this time. This ratio is dynamic; progress towards affluence brings down the ratio from 6 to 3, further aggravating the demand on resources and emissions generation from assets under construction and assets in place.

García Bacca observes that prior to the Renaissance an otherwise exponential growth is refrained by an equal exponential constraint. For example, population with a high fertility rate was restrained by an equally high mortality rate. Per capita consumption followed suite with the addition that production was mostly in the areas of needs. After the Renaissance, population fertility rate remained high but the mortality rate decreased, thus population numbers grew exponentialoid and the artifacts consumed by the larger number of population also grew exponentially. Knowledge, inventions, technology, and science acquired an inordinate efficiency that according to Born 1969 released the intrinsic exponentialoid force by 'un-defining' it, in what García Bacca terms 'trans-finite'.

The concept used is an exponential growth that is unbounded, un-restrained by (a) the diversity and number of inventions, (b) the amplification of the efficiencies of the inventions and

(c) by tapping knowledge beyond that of the natural senses. Such growth of originality unleashed inertial processes that were static (MPC Phase I), now becoming dynamic (MPC Phase II), especially during the Industrial Revolution. The unstoppable inventions in all the orders or fields of knowledge and practice were at the expense of nature (Raven and Berg 2004). This explosion of inventions, knowledge, technology, and science resulted in the domination of the restraining forces of the exponential found within both nature and artifacts (MPC Phase III).

We propose to confirm, modify or reject our found list of parameters through the additional sources: First, we use hermeneutics (Mugerauer 1995) to analyze the Industrial Revolution, a historical period from the 1700's, focusing on identifying the mentioned elements that influence building construction. Second, we search the building construction in increasing level of granularity to confirm, modify or reject the assumptions made regarding these elements of influence. Specifically we look at the history of the high-rise building type.

High-rise buildings evolved significantly since the 1700's and thus embody the progress of the Industrial Revolution. We selected the high-rise building as a surrogate of the industry to confirm, modify or reject the elements derived from the IR. Third, we search the invention and

Table 4.1 Expected Elements of Influence (Actors)

[1] **People – needs, wants, demographics** (Social Values)
[2] **Legacy – historical elements of the industry and world-views** (Historical Values)
[3] **Organizational Structure – self-organization (group, trade, craft, union, and profession), non-monolithic industry, loosely coupled system, meta-industry** (Autonomous Organizations)
[4] **Knowledge Transfer – historical legacy, capacity to learn** (Education)
[5] **Entrepreneurship – Economic ambient and motivations** (Economy)
[6] **Inventiveness – Technological inventions, innovations, science** (Resourcefulness)
[7] **Regulatory framework – Abide by internal and external laws, regulations, codes and standards** (Government)

evolution of specific components of the industry such as air conditioning, and elevator, to confirm, modify, or reject the assumed elements of influence in our pilot study.

4.4 HISTORICAL ELEMENTS OF MECHANISMS FOR CHANGE

The most difficult problem from a historical perspective is that of explaining why - not simply the how or what – change occurs. The discussion of the causation of development and growth is a subject of much debate that in the end, neither empirical evidence nor theoretical reasoning is likely to settle the ongoing disputes. The parameters are complex and un-amenable to a replicated analysis of the laboratory, with the imputation of weights to each of the many determinants, even in a limited situation, a *fortiori* in general. This very complexity and imprecision precludes demonstration that any given explanation of events, however plausible, is the only explanation[113].

After analyzing the three phases of the Industrial Revolution, Landes (2003) comes to a succinct list of elements that come closest to being ‘prime movers’ or mechanisms for change[114]: (1) the increase in knowledge, both scientific and technical; (2) a new spirit of international cooperation (far from perfect but better than isolationism and nationalism); (3) an increase in economic knowledge (also far from perfect, more complex and convoluted); (4) a commitment to change and growth (versus fear of change and active work to dampen its effects). This has lead to another form of revolution: The revolution of expectations and values.

The following schema is based on what Robert Merton has called middle-range hypothesis, that is, generalizations about a closely specified phenomenon or relationship based on a given body of empirical data; as such, they are essentially explanatory or descriptive,

[113] Landes (2003) describes this state of economic development as a drama that includes among other things politics as well as technology.
[114] Enduring factors that would account for what appears to be new long-term trend.

though they may have predictive implications. Landes observes that this model is not worthless or anathema because it is not empirically anchored. “If well constructed, it offers an analytical pattern against which to hold the experiences of history and appreciate their elements of uniqueness and uniformity”. The value of such a model is thus heuristic rather than informative; it does not ‘tell’ what happened but helps one to find and ‘understand’ what happened. In other words it is not a cinematic presentation of actual events but an interpretative narration of events with the intent of rationalizing some form of understanding of those events.

Against this model, we will then proceed for analyzing and comparing the findings of building construction mechanisms for change and its capacity for change`.

People (demographics)

It took mankind hundreds of thousands of years to learn to grow crops and domesticate livestock and, in so doing, to rise above the level of subsistence of a beast of prey, however efficient. The increase food supply that this Neolithic revolution provided made possible a substantial growth of population and a new pattern of concentrated settlement with specialization of labor that had the most fertile consequence for human intellectual development. It took another ten thousand years to make the next advance of comparable magnitude, the industrial breakthrough that we call the Industrial Revolution and its accompanying improvements in agricultural production. Once again, the results have been a huge increase in population numbers able to overcome Malthusian Positive Checks, more and bigger agglomerations of people, greater specialization of labor and rapid intellectual progress, at least in the domain of science and technology: From railroad, to automobile to airplane to jet and space exploration to cite obvious examples of exponentialoid form of travel in terms of speed and in terms of numbers of people and miles per person.

Legacy (Social attitudes, culture, etc)

The interplay of legacy may be followed in the history of the French[115] economy. Before the WWII, the modal enterprise was family-owned and operated, security-oriented rather than risk-taking, technological conservative and economically inefficient. The 1920's saw a rebirth of the technocratic tradition on the basis of a new cult to science, technology and rational organization with reconciliation between mercantilism management (stressing productivity) and the economy of free enterprise (stressing growth). Jean Monnet *Plan de Modernisation* in 1947 concentrated on a few selected sectors of economic activity, then widening its purview as the economy grew and improving national accounts furnished a wider and stronger basis for forecasts and planning. Expansion was the primary aim, but not without gains in productivity.

Typically of French internal criticism, one economist said that the French accomplished their postwar growth in spite of the plan; and another has argued that indicative planning is nothing more than a kind of revival meeting, in which the planners cheer on the industrialists and hope for the best. No other west European country has placed so much reliance on planning, even indicative planning, as the French. The question still remains, as in the case of the French, whether these elements of centralized planning and control have in fact promoted growth or to put the query contra-factually, would growth have been any slower in their absence?

In Germany, it was unnecessary to plan the growth of the country's productive capacity as a formal exercise in prediction (as in the French manner) because what had to be done was essentially to reconstruct something which had existed before. The guide-lines were provided by the past; there was no need for a German Monnet to invent them.

[115] The French, as we have seen had a heavy legacy of Malthusianism and technological conservativism to overcome.

Organization

Growth, in terms of organization, is a marriage of knowledge and action. It is not something produced by impersonal forces of supply and demand, or something that follows automatically from new knowledge and ideas, a *deus ex machina* drama, it requires organization.

Knowledge Transfer

The general trend is the ever-closer marriage of science and technology, with certain independence between them that received stimulus and inspiration to close the gap from technology towards science rather than the other way. Beginning with the middle of the nineteenth Century a close alliance develops: if technology continued to pose fruitful problems for scientific research, the autonomous flow of scientific discovery fed a widening stream of new techniques. The cognitive content and range of both activities grew and were bound to touch and join forces in certain areas of common concern.

The gap between science and technology is far too wide for direct communication (see Kuhn's Incommensurability). The link is provided by two intermediaries: applied science (with the aim at control rather than knowledge and converts the discoveries of pure science into a form suitable for practical use); and engineering (which takes the generalities of applied science, along within a host of other considerations, economic, legal, and social and extracts those elements needed to solve a particular technical problem, whether it is a building, a bridge, a plant or a machine.

Knowledge has a supply and a demand side. On the supply side, the establishment in the 1790's of institutions of engineering instructions staffed in part by men of theoretical preparation made it possible not only to transmit certain elements of contemporary science (sometimes erroneous) but more importantly, to equip them with the tools of analysis and attitudes of mind that make it possible to pass from the abstract to the concrete, the general to the specific and vice versa. On the demand side, the nature of the newer fields of industrial activity, organic chemistry, electrical engineering etc… tended to diminish reliance on the traditional combination of empiricism and common sense along with tinkering[116] and impose a more scientific approach.

The task for invention was getting steadily more complex, the matter of invention more recondite and as a result applied science (such as standards of measurement for precision manufacturing developed by the necessities to interchange parts during WWII) was a more efficient key to the unknown, hence more prolific of innovations. The growth of scale turned what once had been negligible elements of cost into potentially serious sources of loss: The smallest economy in a steam plant that consumes a ton of coal a minute can save thousands of pounds a year. This does not diminish the fact that empiricism and serendipity continued to play a fruitful role well into the twentieth Century but the need for new materials made recourse to precise measurements, chemical analysis, and microscopic metallographic indispensable, sharper tools in the service of empiricism. Scientific principles became essential by the forces of competition that required deliberate and planned experimentation and innovation if not inventions.

Education

Early during the Industrial Revolution, it did not make much difference in the eighteenth Century how much instruction a man had received. The recruitment of talent was on other grounds; wide avenues of mobility were open to the unschooled as well as the schooled; and many a man taught himself or learned by experience the knowledge and skills required for his work.

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[116] Admittedly, the ingenuity of man as tinkerer and doer almost surpasses belief: Note the lead of steam

From this attitude we now come to an interesting anomaly of newly graduated engineers who are paid as much as professional with decades of experience, what was previously considered preferential treatment of beginners as a temporary maladjustment of the market, a lag in the response of supply to increased demand. There is good reason to believe that this imbalance will persist and even increase due in large part to the superior knowledge of those who have received the latest instruction, who have been trained in schools whose curriculum depreciates and is transformed, faster than the human products it turn out[117].

Myth warns us that the wresting and exploitation of knowledge are perilous acts, but man must and will know, and once knowing, must not forget, (also see Ellul's 1954 quote).

Entrepreneurship

Perhaps the most extensive study of entrepreneurial attitudes for any European country was conducted for the Political and Economic Planning (P.E.P.) which examined forty seven firms in a representative sample of industries. Management was classified into three groups: The 'thrusters' who were oriented to change and growth, disrespectful of the traditional rules of the game, open-minded in matters of hiring and promotion, sensitive to objective criteria of performance, and so on; The 'sleepers' who were not 'growth-conscious', preferred not to 'rock the boat', but did not make the use of modern techniques of cost accounting, would not hire good men away from competitors, were indifferent to R & D, and so on; and those who fell somewhere in between the ideal types.

The results were compared to their respective company performance and showed not only a good correlation between attitudes and record by industrial branch, but what is more to the point,

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engineering over thermodynamics.

between attitudes and the record of the companies within the same branch. The most 'thrusting' branch was electronics and ship-building the least and within each of the industries, the 'thrusting' firms generally had the best record of growth of capital and the highest earnings on their capital.

The survey is found to be unambiguous and probably reliable as supported by similar inquiries in other contexts. The import of the correlation is less clear. One might well argue that it is growing, profitable industries and companies that produce 'thrusting' management, rather than the reverse. However, if growth, that is, demand, were the decisive and autonomous determinant, one would expect greater uniformity of entrepreneurial attitudes within a given industry and furthermore, in terms of the criteria used, the most conservative firms within an industry might well be expected to show the best performance, since these are the ones that tend to nurse equipment as long as possible, write down assets rapidly, and accumulate reserves rather than distribute profits.

Given this bias, the superior results of the 'thrusting' firms are the more impressive. One conclusion can be made: enterprises of the same branch perform differently under the same conditions of demand and technological opportunity. It is reasonable to attribute part of this variation to the quality of entrepreneurship and management.

The trouble is that entrepreneurship is a difficult factor to specify and assess. Its characteristics do not lend themselves to quantification (hence the economist's almost instinctive distaste for the whole subject); and they are so overlaid by other considerations that it is almost impossible to segregate their influence. What is more, entrepreneurship is not homogeneous:

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[117] According to Stelson (1961): Teachers of scientists and engineers labor under the threat of accelerated obsolescence: a man who does not retool constantly is unfit to teach graduate students after ten years, advanced undergraduates after twenty.

the entrepreneur, that is, the decision-makers of the economy, includes not only the traditional owner-operators and the newer class of pure managers, but a growing number of government bureaucrats and technicians, some of them assigned to the actual direction of productive enterprises and other acting through influence.

Inventiveness

Landes (2003) offers the following personal middle-range conclusions: (1) backwards economies develop faster than their predecessors, that given what one writer calls the tension between their existing state and their potentialities, their industrialization takes the form of an eruption[118] although the non-economic obstacles are formidable and extraordinarily resistant. The initial spurt of growth, is a making-up of lost time but there is no reason to assume that this pace can be maintained indefinitely; (2) It is generally asserted that follower countries base their breakthrough to industrialization of heavy rather than light manufactures – on iron and steel, mining, chemicals. This argument is generally wrong and ignores historical validity of the law of comparative advantage. Obsession with heavy industry has only a coincidental connection with economic vocation of a country; (3) We frequently assume that follower countries will adopt the most advanced techniques and equipment available. This may be based on deceptive common sense: if one is going to buy machinery, one might as well buy the best (even with an apparent superabundance of labor, skilled workers are scarce and thus labor saving devices more necessary than ever!). Here too historical fact will not support this generalization: Continental industry developed with equipment that was already obsolete across the channel for two reasons: (a) for all the scarcity of skill, relative factors of costs in the follower country favored labor-

[118] This had not come into being at the time of the first edition in 1969, but it is clearly exemplified by the explosive economic growth of China as depicted in Chapter Two. The more backward the country – the bigger the gap between its economic performance and possibilities – the more necessary the intervention of authority in promoting

intensive techniques; (b) the choice of production functions was not always governed by the rational calculations of theory (habits, social prejudice, entrepreneurial caution all led to a relatively conservative investment policy). That is, the followers were poorer in capital and rich in manpower.

The general conclusion to be drawn from all of this is that the complexity of economic development, in particularly when it takes the form of industrialization, affects all aspects of social life and is affected in turn by them[119]. Professor Blumer has come to the conclusion from another direction: Rather than deny or affirm *a priori,* whether for analytical convenience or out of logical conviction, the influence of the non-economic on the economic (and vice versa) he has looked at the wide variety of human experience in this regard and induced wherefrom that the relationship is so diverse and free in its working, and that so much of what is often derived from economic development, population growth for example, is in fact autonomous, that one is not justified in speaking of uniform causal ties or influences. He even goes to the extreme, for the record, that economic development and industrialization are ‘neutral’ and have no specific or necessary effect on social institutions.

This dissertation poses that there is a wide range of links, direct and indirect, tight and loose, exclusive and partial, and that each industrializing society develops its own combination of elements to fit its traditions, possibilities and circumstances.

Regulatory Framework

When all the complicating circumstances are stripped away – changing technology, shifting ratios of cost factors, diverse market structures in diverse economic and political systems – two

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growth (Gerschenkron) however in so far as the attitudes and values of the society are such that its members will not respond creatively or rationally to opportunity, direction and stimulation from above are indispensable.

[119] This is not intended to be the typical flight of the historian into the refuge of multiple interrelationships.

things remain and characterize any modern industrial system: rationality[120] (which is the spirit of the institution) and change (which is rationality's logical corollary, for the appropriation of means to ends, that is, the essence of rationality implies a process of continuous adaptation).

The significance of this principle is obvious: just as the industrial system tries to combine non-human factors of production efficiently, so it will seek to maximize its return from wages and salaries by putting the right person in the right place. A person is chosen not for who they are or whom they know, but for what they can do and what they know. The logical concomitant of this is mobility with a premium on easy movement of labor power, technical skills and managerial talent. A caveat: All enterprises and industries and sectors fall short of absolute rationality yet survive and even flourish thanks to the imperfection of the market place, so societies live and even flourish in spite of the contradictions of their structure. However deviation from economic and social logic entails costs, and if pushed too far can have analogous consequences for an entire nation and nowadays for the regional and even global community.

The regulatory framework in construction mediates the fragmentation of the industry, the multiplicity of players and serves as a mean of generating standards. Carassus 2004 observes that the sector system is mediated by a large number of institutional regulations. These regulations may concern the structures (building permits, construction codes, product and service certification), the firms (firms standards, codes of professional practice by governing institutions and professional groups, labor management, guilds, unions), the environment of firms (procurement methods, funding, tax, R&D support, education and training institutions) and the mode of application (international, national, regional, local) and private institutions (industrial, unions, consumer organizations) among others.

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[120] The adaptation of means to achieve an end.

4.4.1 Summary of the Industrial Revolution regarding Elements that influence change

We have identified salient elements that have influenced changes through different phases of the Industrial revolution. Furthermore we analyzed the recorded flow of changes throughout several industries during the different phases of the Industrial Revolution from the focused perspective of the ten elements.

A summary table of the elements (actors) across a pre-Industrial Revolution, I-IR, II-IR and III-IR phases is attached using the concept of Malthusian Positive Checks sign convention. In other words, before the Industrial Revolution, the ten actors (elements that influence change) contributed marginally to change (item 2), except climate change that affected agriculture therefore they are signed as (positive) that is, suppressing change, maintaining status quo. Item 1, People (Population Dynamics –numerical increase in population and Demographics – increase in affluence) began exerting increase influence during the II-IR and real influence in the III-IR.

Social Attitudes (cultural legacy) shift from maintaining the status quo for example with family owned business to regional, national and eventually multinational during the I-IR. Entrepreneurship, item 4 followed the shift in social attitudes during the II-IR while Organizational and Technology (items 5 and 6 respectively) began exerting their influence during the I-IR. Organizational influence was felt through the insertion of management methods to improve efficiency, training etc in productivity and artifacts for general consumption. Technology's influence was felt through the move from the earlier tinkering towards the application of science in other than first time technologies (i.e. step wise advancements of existing technologies) and later on chemistry, nuclear physics etc. Item 7, Inventiveness took off during the II-IR giving a strong impetus to the I-IR. Regulatory Framework, item 8, started with the move from imperial controls to increasingly democratic controls, freedoms and private ownership of lands, inventions and businesses. Item 9, the Economy exerted its influence during the II-IR when capital was required for private and public expansion of previously mentioned initiatives, especially Education, item 10, that with knowledge transfer of highly scientific experiments into technology gave a boom to the economy.

During the 1-IR a number of actors began shifting from a positive check (keeping the status quo) to a negative position allowing or encouraging change (thus the positive/negative). This process accelerated during the 2-IR and 3-IR and continues up to this day, thus the

Table 4.2 Industrial Change "Positive Checks"

Item	Influence/Phase	Pre - IR 1100-1700	I- IR 1700-1850	II- IR 1850-1940	III- IR 1940-1990
1	People Population Dynamics Demographics	+	+	+/-	-
2	Climate	+/-	+/-	-	-
3	Social Attitudes Cultural Legacy	+	+/-	-	-
4	Entrepreneurship	+	+	+/-	-
5	Organizational	+	+/-	-	-
6	Technology	+	+/-	-	-
7	Inventiveness Tinkering to Innovations	+	+	+/-	-
8	Regulatory Framework	+/-	-	-	-
9	Economy National Multi-national	+	+	+/-	-
10	Education Knowledge transfer	+	+/-	-	-
	+ Totals	10	9	4	0
	- Totals	2	6	10	10

(negative) indicating that the restraining forces of the exponentialoid are negated thus the forces at play are allowed to increase logarithmically. The significance of this table is that the elements that have influenced change throughout the several identified phases of the IR have a progression from keeping the status quo to encouraging change first and then maintaining the change momentum. In a vector this corresponds to a change of sense affecting direction and magnitude. The magnitude of the change is the third vectorial component that is difficult to gage.

Instead of looking at a specific industry for the descriptors (elements) we selected the entire period and the amalgamation of industries (since building construction draws from multiple industries) for the descriptors of change. The reason behind this choice is that the model of interaction of several sectors (meta-industry) is more like building construction's model where several sectors link through a service provider to perform a capital asset creation, a project whose impact in the economy is felt throughout its life-cycle. Previously we stated that building construction is a meta-industry (an industry that links multiple industries), Landes (2003) uses the concept of a "family of links" that is applicable to building construction.

Others like Carassus (2004) accept the economic definition of construction as a sector but with reservation and call it a sector system to encompass the notion of a mesoeconomy where construction, not only includes development, infrastructure, buildings but also facility management to account for a total life-cycle process. Mesoeconomy deals with entire sector economies and include socio, political and other aspects that otherwise are in the background (Preston 1984 cited by Carassus 2004).

4.4.2 A link between the IR and building construction

In this model, Building Construction is a complex (Bertelsen 2003), multifaceted environment with a wide range of links. These links are direct and indirect, tight and loose (Dubois and Gadde 2002), exclusive and partial, and each culture (society, company, or association of service providers) develops its own combination of elements to fit its traditions, possibilities and circumstances and mostly come together for the limited duration of building a capital asset, a ‘project’ with a unique life cycle.

In this light we see Building Construction as a background that antecedes, affects and is affected by the Industrial Revolution. The proportion of population working in Building Construction has always surpassed that of any other industry (perhaps with the exception of agriculture) in most countries during recorded history. FDR New deal was based on public works employment to lift the nation from a severe economic depression.

4.4.3 Other considerations regarding metrics

The gap between perceived ‘best possible’ and ‘best practical’ practices at a given time is perceived as the rationale behind ‘changes’ of the Industrial Revolution. In Building Construction, like in other industries, we do not have the data and historical information to articulate ‘best possible’ and ‘best practical’ practices at any given time. This is unfortunate because it is our intuition that in the Building Construction sector the ‘capacity for change’ resides in this gap. The story of the Industrial Revolution is how this gap has been narrowed in a particular time by the mechanisms for change that have engendered a self perpetuating enterprise permanently affecting the general economy, where building construction resides.

Manufacturing, as well as building construction, have a preference with cost and price which is the narrow economic perspective of any industry. However this has not always been the building construction primary motivator but as in a meta-industry, previously the overall creation of value used to be the driver. Value creation, another form of the gap between best possible and best practical, however does not lend itself for metrics like the terms of 'best possible' and 'best practical' practices are recalcitrant, reluctant to be translated into performances and efficiencies. In this sense the Industrial Revolution is the surrogate for Building construction performance and efficiencies.

For example, Landes (2003) subdivides industries into two classes: those that transforms[121] and those that assemble[122] and specifically mentions building construction as in the later class ('of which may undertake some transformation but whose salient characteristic is that they put their work together'). The major breakthroughs of the 1-IR were first in those that transform, the 2-IR vacillated between transformation and assembly and the 3-IR moved into full swing on the assemblage, organization, accountability, estimating and management. However in both types of industries, the inventions (first time technologies) benefiting through the impetus given by prime movers were the repositories of the major achievements in efficiency.

The link between IR achievements and building construction are well documented. For example: Certain aspects of the building construction have benefited from the IR more than others. Structure is one early aspect of transferred technology and application from the light and heavy sectors of the IR. During the 1-IR heavy industry machinery and rail transportation benefited heavy building construction but light construction had to wait for the 3-IR in electricity, electronics and controls to achieve substantial benefits.

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[121] Direct smooth work flow from start to finish of the process with one main stream of activity and a sequential spatial arrangement of operations is all that is required.

[122] All other that are not of a direct transformation order with their own peculiarities characterized by nodal rather than linear flow: Imprecision, variation, custom work, skilled craftsmen, fitters, masters of a technique (able to maintain and use their own tools) and autonomous nodes (activities and people) i.e. subcontractors.

A contrasting example: The IR was played differently in different countries portraying the tendency of some countries towards diversification and flexibility and others towards specialization. Building Construction specialization had occurred much earlier than the Industrial Revolution and it already had endogenous diversification and flexibility. Particular industries, as they linked with building construction, brought exogenous efficiencies moderated by social values. In building construction like in the industrial revolution, availability of cheap resources was and is a hindrance to innovation that is also anchored by societal values and norms. For example, in the 1800's if the following statement about the industry in England and the Continent can be made, how does this statement reveals building construction's 'state of the art' at that time?

> In these circumstances, the industry made little attempt at standardization, except in the manufacture of spinning machinery and similar apparatus, where the volume of demand permitted and encouraged the appearance of types and models. Even here, however, the manufacturer made everything to order, and every order was in some way different from the one before. There was no production on speculation… interchangeable[123] parts were unknown; there was little or no working to gauges; and the file was still the machinist's most important tool.

The following are other IR statements that appear to be transferable to the building construction industry: "The effects of weak demand were aggravated by the dispersion of critical raw materials." In an age before transportation what would this statement affect the state of the art in building construction? Or the following statement regarding change and diminishing returns of industrialization as revelatory of building construction: "change was built into the system, and innovation was if anything more frequent than ever. But the marginal product of

[123] Interchangeable parts require a degree of precision that was either not available or used in the early part of the Industrial Revolution and is affected by the purpose of the product; the material employed. Both are related to volume of use to make the effort worthwhile. The first area to standardize and have interchangeable parts is the manufacture of small arms, where this level of quality was needed for military use. Some countries social values

improvements diminished as the cost of equipment went up and the physical advantage over existing techniques fell." Without a fixed market, innovations have a hard time proving profitability. According to Landes (2003, pg 276) "The title of one history of a chemical firm in the late 1800's 'One Thing Leads to Another' is a surrogate of the long-sought secret of transmuting and creating matter," and the thread of this dissertation, a search for the change mechanisms behind how one thing leads to another". So what has the III-IR lead to?

4.4.4 The Fourth Industrial Revolution (IV-IR, 1990 – present)

The III-IR has led to a Global Economy that is now typologically characterized as the IV-IR (1990 – present). Friedman, 2005, The World is Flat, a Brief History of the Twenty-First Century is a compendium of the forces at play in a global economy, namely: Work-Flow Software; Open-Sourcing; Outsourcing; Offshoring; Supply-Chaining; Insourcing; In-forming and the Steroid of the current conditions. The steroid of the current condition is interpreted in this dissertation to refer to the exponentialoid that the confluence of these elements of influence has created (see Table 4.3).

His study points to the same list of elements, actors, behind the global economy where work can now be done anywhere in the planet by equally educated and prepared individuals that have access to digital technology (the globalization of the effects of education). The technology has increased the potential of individuals in developing countries to compete for work (the globalization of entrepreneurship). In Friedman's (2005) words, anything that can be digitized will be subject to exporting to countries where the cost of living is less, bringing the possibility of increasing in such countries the standards of living and thus accelerating the move from developing to developed status. The global actors, analyzing Friedman's work are accelerating

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deemed their industries like 'custom tailors' such as Britain and others saw the rationality of simplification, not only economic change but social, cultural, and political. In other words, the demographic change previously mentioned, is a reality.

Table 4.3 characterizes the elements that have influenced change in the early part of the twenty-first Century with the 'steroid of the current condition' as the affected exponential (economic growth, resource consumption, emission generations, population growth and affluence) proportionally increasing the magnitude of the problems affecting climate change.

Table 4.3 IV Industrial Revolution, Early XXIst Century Elements of Influence of Globalization, the demographic migration from developing to developed of significant population numbers.

Item	Element of Influence	Influence/Phase	1990	1995	2000	2005
1	Knowledge Transfer	**Fiber-optic/Digital Cabling**	+/-	-	-	-
2	Knowledge Transfer	**Workflow Software**	+	+	+/-	-
3	Knowledge Transfer	**Outsourcing**	+	+/-	-	-
4	Inventiveness	**Open-Sourcing**	+	+	+/-	-
5	Entrepreneurship	**Offshoring**	+	+	+/-	-
6	Entrepreneurship	**Supply-Chaining**	+	+	+/-	-
7	Entrepreneurship	**Insourcing**	+	+	+/-	-
8	Legacy - historical	**Informing**	+	+	+/-	-
9	Regulatory framework	**Standards**	+	+	+/-	-
		+ Totals	9	8	7	0
		- Totals	1	2	9	9

introducing the inter-firm principle of standards (Woodbury, 1960)

4.5 BUILDING CONSTRUCTION ELEMENTS OF CHANGE

The evolution of the generated object (a building) reflect most of all the breeding ground (of ideas, values, creativity, entrepreneurship, theories, knowledge transfer[124], process creation, etc) that exists within this amorphous, fragmented, industry of industries, called building construction. In other words, the building is a depository of the forces that created it. Internally, these creative forces and process that originally resided in the amorphous, organic breeding ground called Building Construction Industry ends up embedded in the one of a kind, in-situ, and a project built by a different team. Externally, the building construction industry of industries is the beneficiary of a larger historical background where other forces reside, such as the ones that comprise the Industrial Revolution. To identify and analyze the internal and external elements of change in building construction we have to first identify one building type, surrogate of the industry and through historical inspection, dissect the elements and actors of the observed physical change.

A building is a physical form with given properties. According to Descartes (Cottingham 1986; Damasio 1994) the properties of forms in the Physical World are Dimension, Shape, Position, Motion, Substance, Duration, Number and Activity. We have chosen the property of dimension, specifically vertical dimension in the study of high-rises (see Table 4.4). In chapter 5 we shall return to Descartes 1989, properties of form.

[124] Up to the Industrial revolution, building construction knowledge transfer was through crafts, guilds, and 'mysteries,' (using what is now termed as first order theories – based on geometry) then during the period known as the middle ages when printing was discovered, knowledge transfer through books (Vitruvius 10 Books) supplemented the above mentioned means. Today, academic training and computer sophistication add modern methods of knowledge transfer (in what is now termed as second order theories, based on change of shapes under load conditions) Sebestyén, 1998).

Table 4.4. Form: Properties of the Physical World. Adapted from Rene Descartes, Meditations on First Philosophy, Cottingham (1986) and Thiis-Evensen (1987)
Dimension: Length, width (clear spans), **height (verticality)** – (walls, floor, ceiling)
Shape: A function of the dimensions, boundaries of extension
Position: A relation between various shapes
Motion: Change in shape position (or Immobile)
Substance: Materials of the shape
Duration: Longevity of shape/materials
Number: Quantity of shapes
Activity: Process of creating the above properties

4.5.1 Synopsis of high-rise history

According to Fitchen 1986, the craft of construction was traditionally based on empirical experience (Ortega y Gasset's 1939 'chance'), learning by trial and error, success and failure, and oral transmission. Materials and forces remained fairly constant. Timber, stone, wind, falling water, animal and human forces. Transformations were mostly accomplished through the application of heat energy. Prior to the 1800's buildings were seen mainly as shelter affording occupants' protection from cold and rain. Prior to the industrial revolution, humanity was hostage to the environment, that is, to the cycles of nature. The work force although could read drawings, was mostly illiterate.

Since the 1800's, and due to technical advances brought through the IR, buildings require pleasant ambience, an acceptable temperature and lighting and other conditions that provide for human comfort met by increasingly sophisticated equipments as technology has progressed. New sources of energy, coal were discovered followed by, fossil fuel, gas, and nuclear energy. Invention and innovation of machinery accelerated.

High rise buildings were largely possible due to (adapted from Fitchen 1986):

1. The discovery of a large new market (building construction) for the expanded steel industry after it had supplied the rails and bridges for America's Transcontinental railroads.
2. The development of the high-rise passenger elevator.
3. The development of Portland cements ca 1820 for foundations and rammed earth (pisé).
4. The eventual electrification of buildings (lights, motors, heating, control systems, etc…).
5. The eventual incorporation of Air Conditioning for thermal comfort.
6. The invention of curtain-wall building skin as separate from the structural frame.
7. The invention of light weight materials for infill and partitions such as gypsum board, light gage metals and hung ceiling systems.
8. Building theories such as modern methods and techniques of analysis, investigation, and mathematical computations with their reliance on tables, formulas and test results.
9. The development and incorporation of code requirements oriented towards life safety issues.
10. Machines inventions augmenting, levering the human reach capacity.

These different methods and practices rarely emerged or came into general use at once. Tardy developments in one phase (or in one place), sudden breakthroughs in another, and long periods of static overlap, have been facts of life throughout the history of building construction pointing to the systemic nature of the industry. Handcraftsmanship was augmented by the machines and its attendant attitudes, methods and techniques. Prior to the modern times, building operations took place in relatively unsophisticated societies but achieving remarkable success in the areas of: [125]

- Site selection and preparation
- The order and sequence of operations
- Construction equipment such as falsework, ropes and ladders
- Permanent features used as aids in the erection of buildings such as scaffolding ties
- Conveyance of manpower and materials to the site

Design and construction were at this time mutually inclusive. Until the Renaissance, the master mason and the master carpenter served in two capacities at once[126] (in 'modern times'

[125] Watson's (1901) coverage of Glasgow Cathedral and Price's (1753) inspection and analysis of the fabric of Salisbury Cathedral, as quoted in Fitchen (1986).
[126] Papsworth (1887):, *"Notes on the Superintendents of English Buildings in the Middle Ages,"* as quoted in Fitchen (1986).

terminology: both architect and builder, also known as the Master-Builder[127]). The way in which a feature or assemblage was actually built sometimes critically affected design. More often than not, the aesthetic design imposed restrictions not only on the use and disposition of the materials but also on the effectiveness of the design itself. (A modern version of this coupling of design and materials can be observed in the current works of Gehry). However, the aim of this study is on the banaustic and operational practices (the evolution, the capacity for change through techniques, technology and the systematic nature of building construction) rather than the aesthetic or stylistic constraints on construction.

The builders in this era were not charged with the finances or raising the money for the construction (nor are they expected to raise the money today) and usually site selection was performed by others (again, a practice that continues today). The builders' responsibilities were to assemble, assign tasks and coordinate the efforts of the labor force and the conveyance and erection of the materials. With regards to the labor force, the responsibilities often included for remote sites, the erection of barracks for the labor force, administration personnel and sometimes security forces. The builders also had to supply ancillary buildings for their tools, equipment and food storage and preparation.

Eventually, humanity become hostage to internal structural calculations (Timoshenko 1953) and computational mechanics, and the modeling of reality backed by controlled experimentation for validation Kersken-Bradley et al., 1991; Ladevéze and Zienkewicz, 1992).

[127] The separation of the architect from the builder follows a pedagogical line where the architect is literate and the builder remained illiterate. However both communicated via graphs, sketches and drawings. In a sense the Master-builder contained its own demise as the Architect became the Master and the builder remained a builder. Most works of art dealing with architecture were intended for an educated audience, the intelligentsia and therefore a prolific number of architectural writings, whereas building construction, not having a literate audience has a relative poor record of written literature. Most information on materials and methods are observed from sketches in the literate of the times. This changed in the 1900's when the building construction trade was incorporated as a curriculum in universities.

Other contributors to the quantitative realm are: Arthur Cayley's 1858 matrix algebra, Hooke's moment-deflection laws, Leibniz's finite difference calculus (functions make discrete changes to the argument) and differential and integral calculus (the argument changes continuously), Crouch and Starfield's 1990 boundary value problems, Edward Lorentz's 1960 chaos theory[128], Leonhard Euler's geometrical forms of elastic curves and buckling columns, Charles Augustin de Coulomb's combined theoretical and experimental work, Claude Navier's 1826 beam theory among others (quoted by Sebestyén 1998) .

Philosophers criticized modern science as characterized by the objectification of the natural world, the re-presentation of the world in mathematical/plastic terms that necessarily leave out accounts of its earthiness, thus setting up the possibility for producing objects without true individuality or thinghood (Heidegger, 1957). Deterministic models are replaced by probability based ones, with the introduction of mathematical statistics and quality controls. Transformations are mostly accomplished through the application of heat energy as well as chemical reactions. In other words, we reach a theoretical state of the categorical plan, causes and consequences, where objects (things) act-but-do-not-talk and in schemas through scalars (magnitudes) and when possible the vectorial forces (magnitude, sense and direction) of the real and the universal pure aspect, supra-individual and supra-specific (Heidegger, 1957). Building construction sub-sectors have respective bodies of theories within their professions. However, Building construction, it is claimed, lacks a proper body of theory (Koskela 2003).

Turner (1986) distinguished six major technological revolutions in construction:

- 1800-1900 Industrialization of traditionally handcrafted and secondary trades
- 1851-1880 Skeleton frame, the use of iron and steel, and later on reinforced concrete to divorce the frame from the envelope or skin (curtain wall)

[128] Chaos theory follows Jules Henri Poincare's theory that minute inaccuracies or uncertainties of initial conditions make it impossible to predict the future precisely. (See PDRI)

- 1900-1950 New metals, alloys and industrial processes for the building skin (curtain wall): aluminum, steel, glass (Sedlaeck et al., 1995)
- 1900-1980 Application of synthetics: sealants, laminates, resilient flooring, polymers (natural rubber, cellulose nitrate, polystyrene, polyvinyl chloride, polyurethane and epoxy)
- 1890-1950 Pervasive use of electrical power and lighting
- 1850-1950 Building services such as heating, ventilating, air conditioning (Heppenheimer 2005) and elevators (Goetz, 2003).

Since then, newer technological applications include among others:

- New or improved building materials: fabrics, asphaltic membranes, geotechnical fabrics, high and super high strength steel and concretes, and structural glazing, improved fire resistance materials, special concretes, engineered wood products, coated and multi-layered glazing, polymer composites (plastics), special paint and coatings, etc.
- Taller and longer span in buildings through design and materials such as pre-stressed concrete (Freyssinet, 1928) and the 70 story high strength concrete Lake Point Tower (1965-68).
- More complex and integrated building services with special consideration to health, hygiene, energy conservation and protection of the environment
- Robotic construction
- Sophisticated Information and CAD systems integrating design, fabrication and construction

According to Sebestyén (1998)[129], building construction had to invent and perfect the following systems (see Table 4.5: *italics of the titles have been added as relevant to his work*) in order to overcome forces and height constraints.

Table 4.5 Building Height Characteristics

1. *Strength of materials:* Structure (reinforced concrete, steel, light interior wall construction)
2. *Theories and practices:* Wind / Earthquake Force Resistance
3. *Energy sources:* **Electricity**, (distribution, motors, pumps)
4. *Circulation:* Vertical Transportation, (**Elevators**)
5. *Boundary definition:* Skin, (materials)
6. *Essential anthropocentric systems:* Mechanical Systems, (Plumbing, **Air Condition**)

[129] "Height has always posed a technological challenge and the development of solutions have marked the progress of construction" Sebestyén (1998).

Structural theories[130] had to be perfected, according to Sebestyén 1998, such as plasticity (Prager), reliability (Freudenthal), finite element analysis (Clough), stability (Shaley), dynamic analysis (Newmark) expert systems (Fenves 1996) and practices such as modeling gravitational and lateral forces, lateral drift and stiffness, oscillation mitigation, limitation of creep, shrinkage and temperature effects, earthquake (quoted in Sebestyén 1998). Electricity, fire protection, vertical transportation and skin are also obvious contributors to changes in the industry.

4.5.2 The high-rise building as a system of systems

Fig. 4.9 shows in a graphic form that the time-line when high-rise buildings increased in height (right margin) exponentialoid is the same time-line when major and different inventions, innovations as well as systems and processes innovations took place (left margin). The changes that took place in the industry from the start of the Industrial Revolution ca. 1700 were, in the words of Garcia Bacca (1989) independent and discontinuous (See Appendix I). What that means is that improvements in water supply do not necessarily infer, imply or demand improvements in waste treatment. Likewise, the advent of charcoal does not force the advent of coal which does not force the advent of oil and so forth. With each independent and discontinuous invention the possibility of an aggregation into a building type is also independent and discontinuous of other building types. Today's logic is post facto, and creates a bias towards understanding how independent and discontinuous each event really was.

How does independent and discontinuous inventions relate to exponentialoids in the worldview proposed by Garcia Bacca? If discontinuous and independent forces conspire to generate an exponential, the straight relationship between cause and effect in an exponential, say in population growth that we have previously seen and rates of birth and death is broken when

[130] As listed by Galambos, 1982 quoted in Sebestyén (1998).

multiple causes that influence birth and death rate are taken into account. That is there are multiple and diverse causes acting at each point in time and to differentiate the cause and the resulting curves, Garcia Bacca calls it an exponentialoid.

An exponential is, for the purposes of this dissertation and in keeping with Garcia Bacca's thinking, an algorithm based on a continuous and dependent cause. For example, human population growth curves are based on human birth and death rates. When multiple and diverse causes or forces may act independently and discontinuously in a pattern of growth that resembles an exponential, the resultant is termed an exponentialoid. The purpose of creating this term is to differentiate it from its cousin, the exponential due to significant differences. That is, when there are multiple and diverse (even independent and/or discontinuous) causes acting at each point in time and to differentiate this from an exponential, Garcia Bacca calls it an exponentialoid. For example, the life changes from technologies, medicine, hygiene, potable water, sewers, agriculture and economy among others act as forces affecting birth and mortality rates. These forces are multiple, diverse, some act independent and discontinuous. In other words, they have origin, direction as well as magnitude.

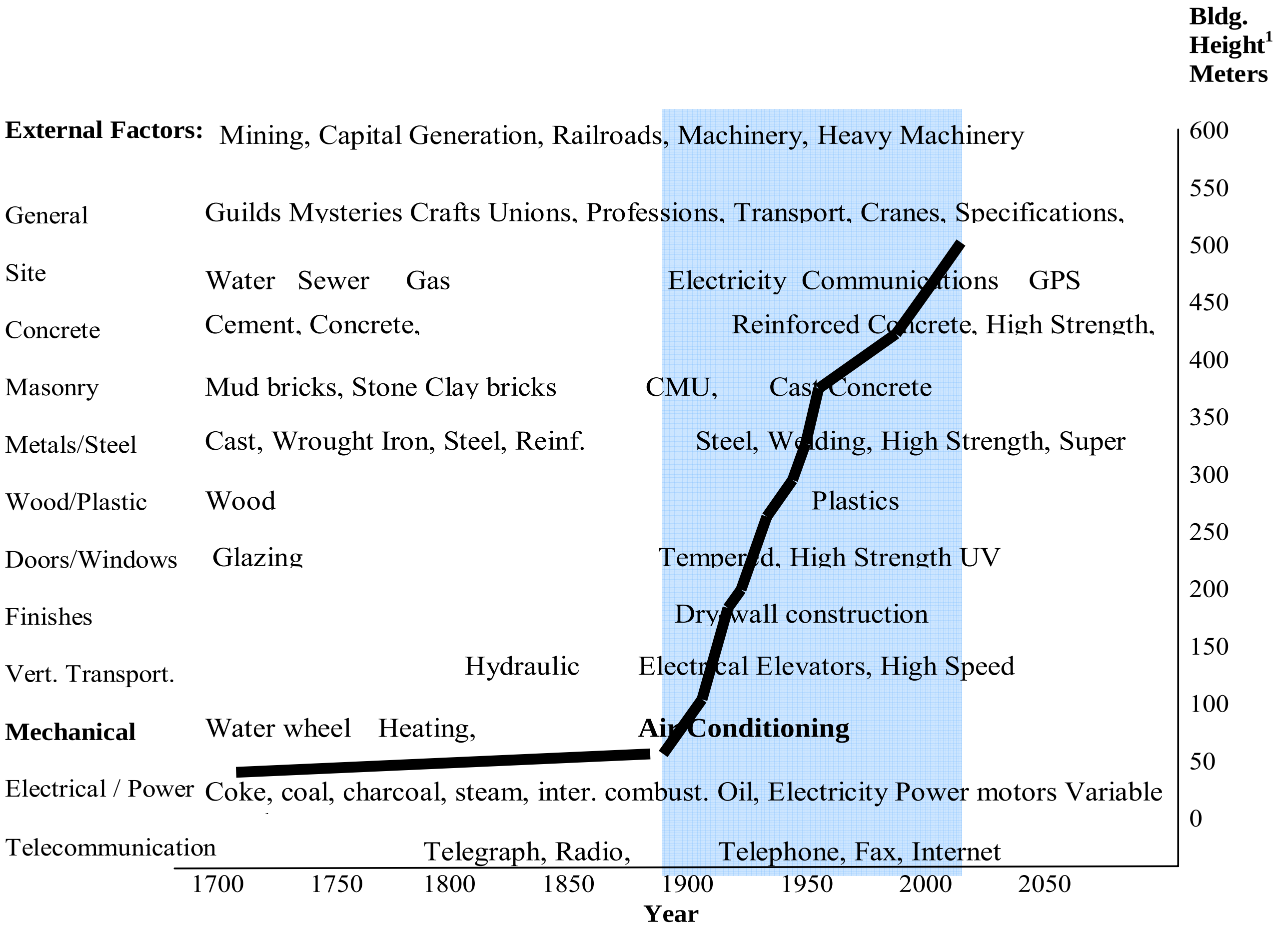
In the population example above an exponential has one variable, rate of growth derived from rate of birth and rates of death. There can be no other introduction of variables in the time line that affect the exponential curve since any cause of death or birth are reduced to the rates. At the next level of integration, those previously mentioned forces that directly and indirectly affect life have different characteristics, one of them is origin, they can be appear, mature and disappear in the time line; their direction changes from birth, maturity, full contribution and decline (hence a taxonomy of change) and the magnitude varies. In other words, this level has a unique language (symbols and meanings) that we need to decipher, understand and then learn how to read, crafting-out its uniqueness and peculiar richness that populate its reality (ref. Popper).

This graph could have been presented in two separate graphs, one showing the time-line of inventions etc and another the time-line of the high-rise building height but we feel that the impact of the relationship between inventions and building height in a time-line would not have been as obvious.

At the top of the graph there are general inventions, technological improvements, etc. that as they were created in time since they affect building construction. The inventions and innovations listed use, in general, Masterformat/CSI categories tracked in the time-line. The darker band shows how a series of independent and discontinuous inventions, innovations, technologies, systems and processes came into being allowing the building type called the high-rise, also known as skyscraper, to become possible.

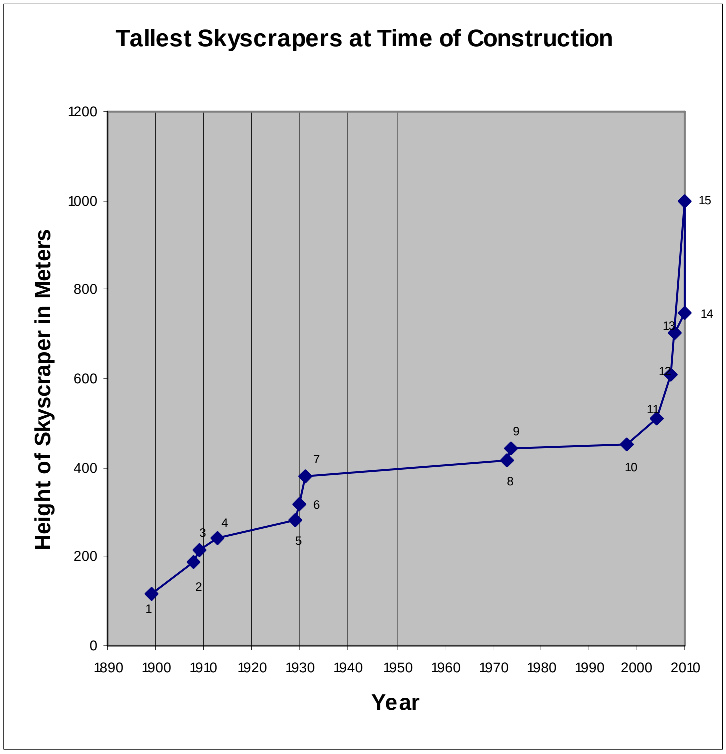
Figs. 4.8 and 4.9 also alludes to a historical glass ceiling with respect to building height (verticality) of approximately 50 meters[131] until the 1900'S, when a series of inventions, innovations and improvements on a number of technologies took place. In other words a number of disparate, discontinuous, apparently un-concatenated, singular events, inventions and systems came to maturity in the historical "background" of the industry, a meta-system and, in the words, (a source of resources Palmer 2004) for the "high-rise building" to emerge. The mechanisms for change from a 50 meter to current heights were in place for designers, builders and manufacturers, the industry (along with the larger economy, culture and other meta-systems) see *Fig. 4.9*.

[131] Buildings (for human habitation or work) in this study do not include self-standing towers such as the Ulm-Munster tower of 161 meters and the pyramid of Cheops at Giza 146.4 meters (Sebestyén, 1998).



[1] From Stafford, Smith and Coull, 1991 as referenced by Sebestyén, 1998

Fig. 4.8 *Historical Graph: Building Height & Inventions / Time Line*



1. Park Row, 118m, 1899
2. Singer Building, 187m, 1908
3. Metropolitan Life Insurance Tower, 213m, 1909
4. Woolworth Building, 241m, 1913
5. The Manhattan Company, 283m, 1929
6. The Chrysler Building, 320m, 1930
7. The Empire State Building, 381m, 1931
8. The World Trade Center, 417m, 1973
9. The Sears Tower, 443m, 1974
10. The Petronas Towers, 452m, 1998
11. **Taipei 101, 509m, 2004**
12. **Guangzhou TV and Sightseeing Tower, 610m, 2007**
13. **Burj Dubai, 705m, 2008**
14. **Al Burj, 750m, Future**
15. **EnviroMission Solar Tower, 1000m, Future**

Fig. 4.9 Tallest High-Rise Buildings existing and ***projected*** *for construction.*

Currently we have another glass ceiling height at approximately 500 m. New materials, methods, systems and technologies have to be created in order to reach 750 and 1000 m and higher. A 1,000 m high-rise, as an iconic project, would have a role in pushing innovation and the diffusion of new knowledge. Adverse climate changes may pose different performance requirements on existing and new structures. The industry is beginning to ponder what these new performance requirements might be, since there is no historical precedence on the magnitude and frequency on wind, fire, ice, snow, flood and earthquake in a dynamic and paradoxical environment. That is, we do not know the boundaries of a new normal as well as the new boundaries of para-normal climatic conditions.

4.5.3 The air conditioning system

We have selected mechanical systems (technical services) from among Sebestyén (1998) list of building systems (see Table 4.1), specifically the history of air conditioning, to study at a greater level of granularity, the elements or actors that contributed to this invention.

Fig. 4.12 showcases air conditioning history, from 1775 to the 1940's, when the inventions and innovations, created independently and discontinuous, finally coalesced in a product that was right for the times (post war) against the sales of units which took off exponentially in the US market alone. The graph is much steeper if the global market of sold units is added. This market is driven for the human want of comfort that relates to population numbers and affluence (affordability).

The story of the evolution of the air conditioning from the first intent to invent a machine that creates ice to the ultimate climate controlling system provides the following Causal Loop Analysis of the elements or actors in the process of invention, innovation and improvements (*Fig. 4.11*) and air conditioning root definition using soft system modeling techniques (*Fig. 4.12*).

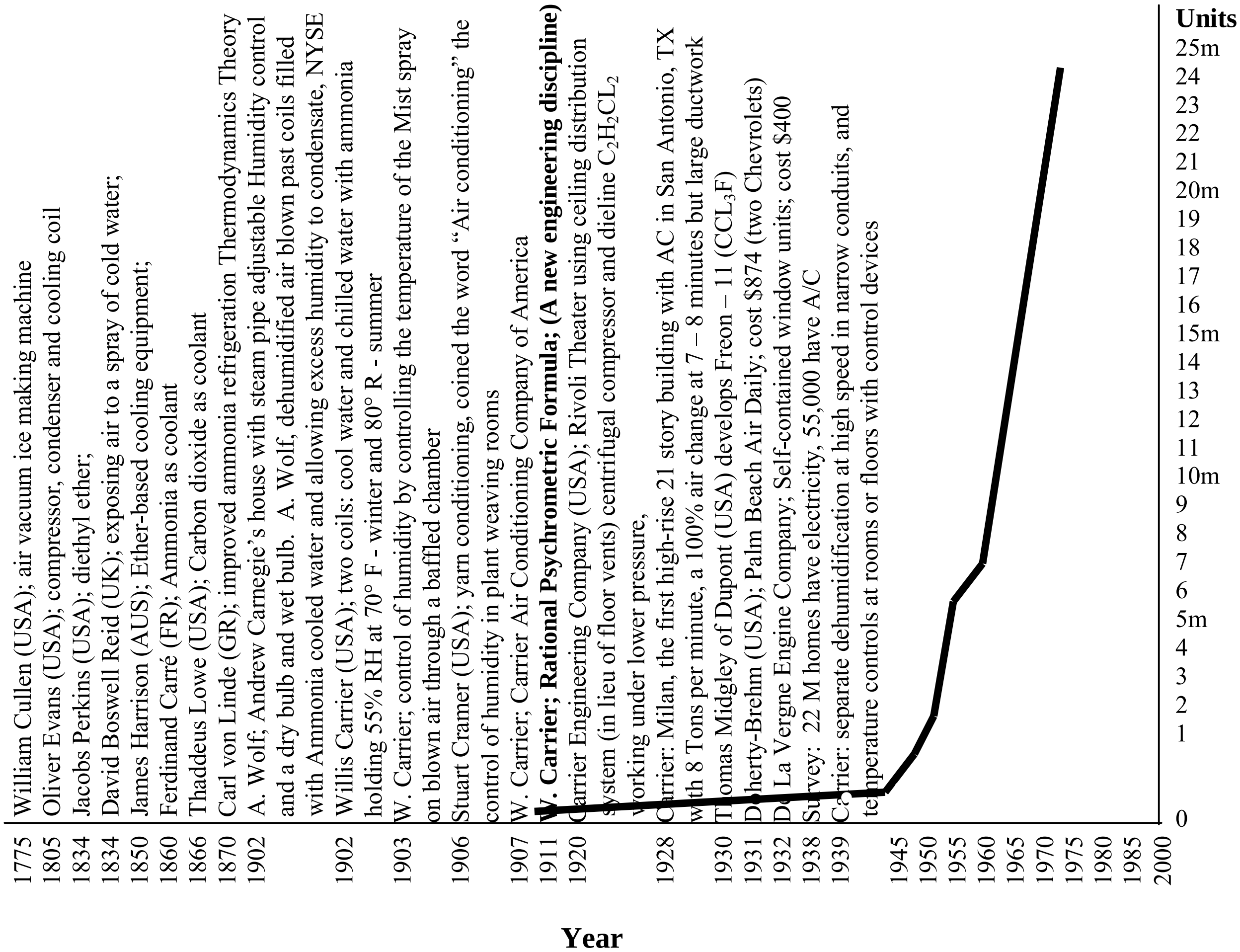


Fig. 4.10 Air Condition History / Housing Units in place time line (based on Heppenheimer 2005)

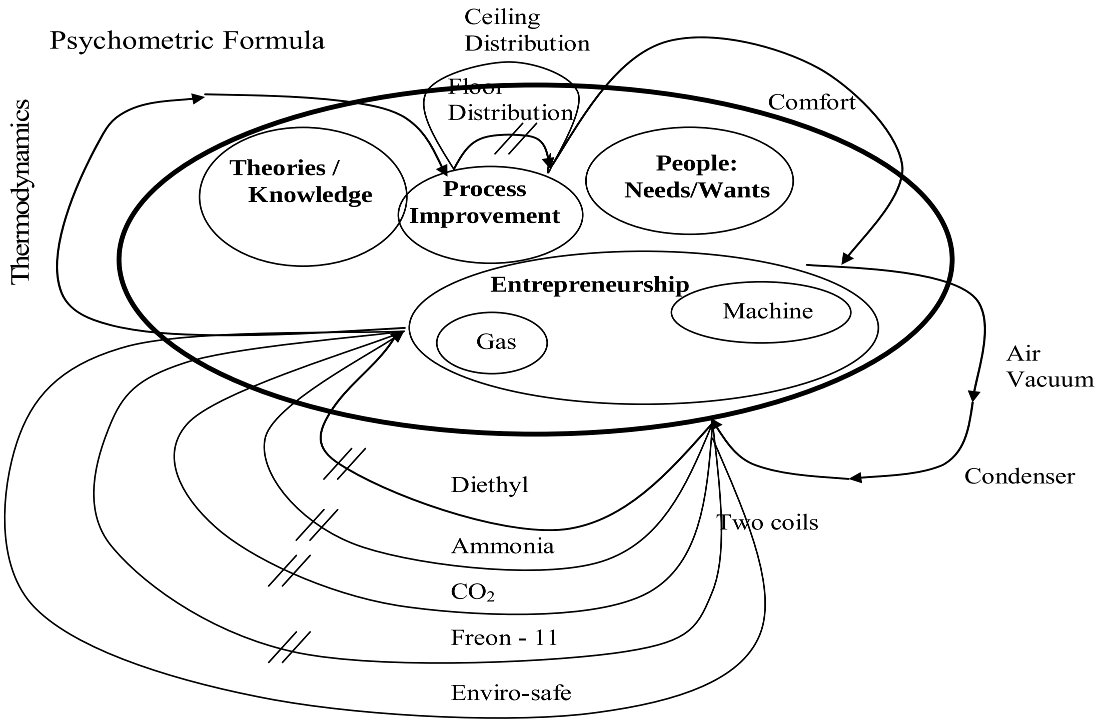


Fig. 4.11 Causal Loop Analysis of AC inventions

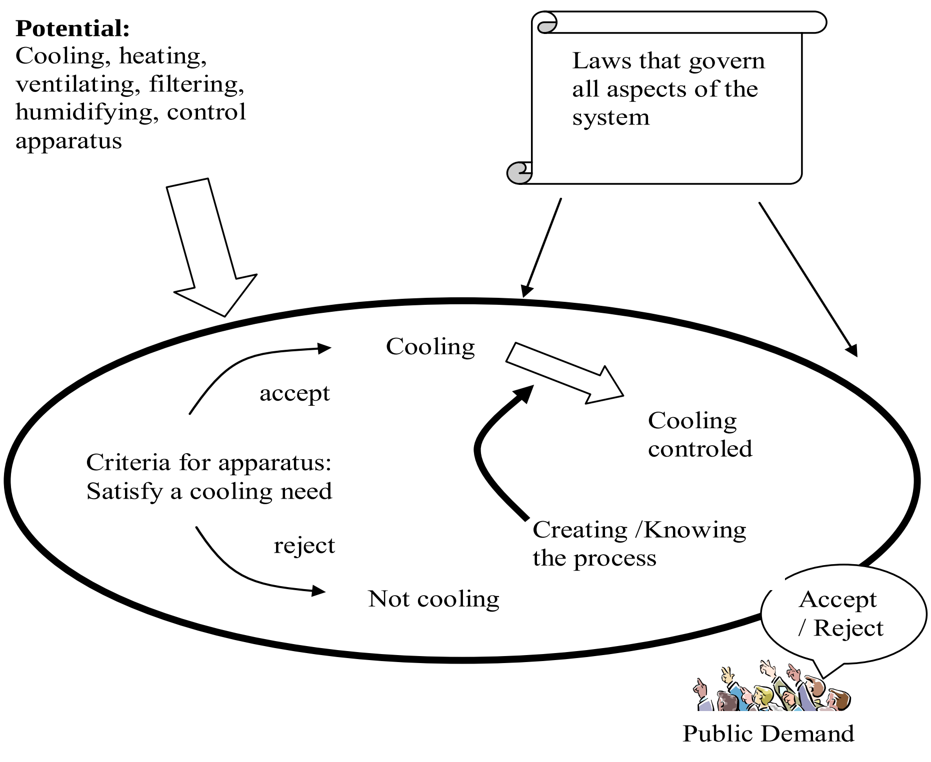


Fig. 4.12 AC Root Definition using Soft Systems Modeling Techniques (Checkland, Rosenhead, Mingers 2001)

4.5.4 The Elevator System

The elevator is a vertical conveyance system created for other than building purposes (industrial need to lift and lower products) but once coupled with human need for safe vertical transportation made the high-rise building design and construction possible.

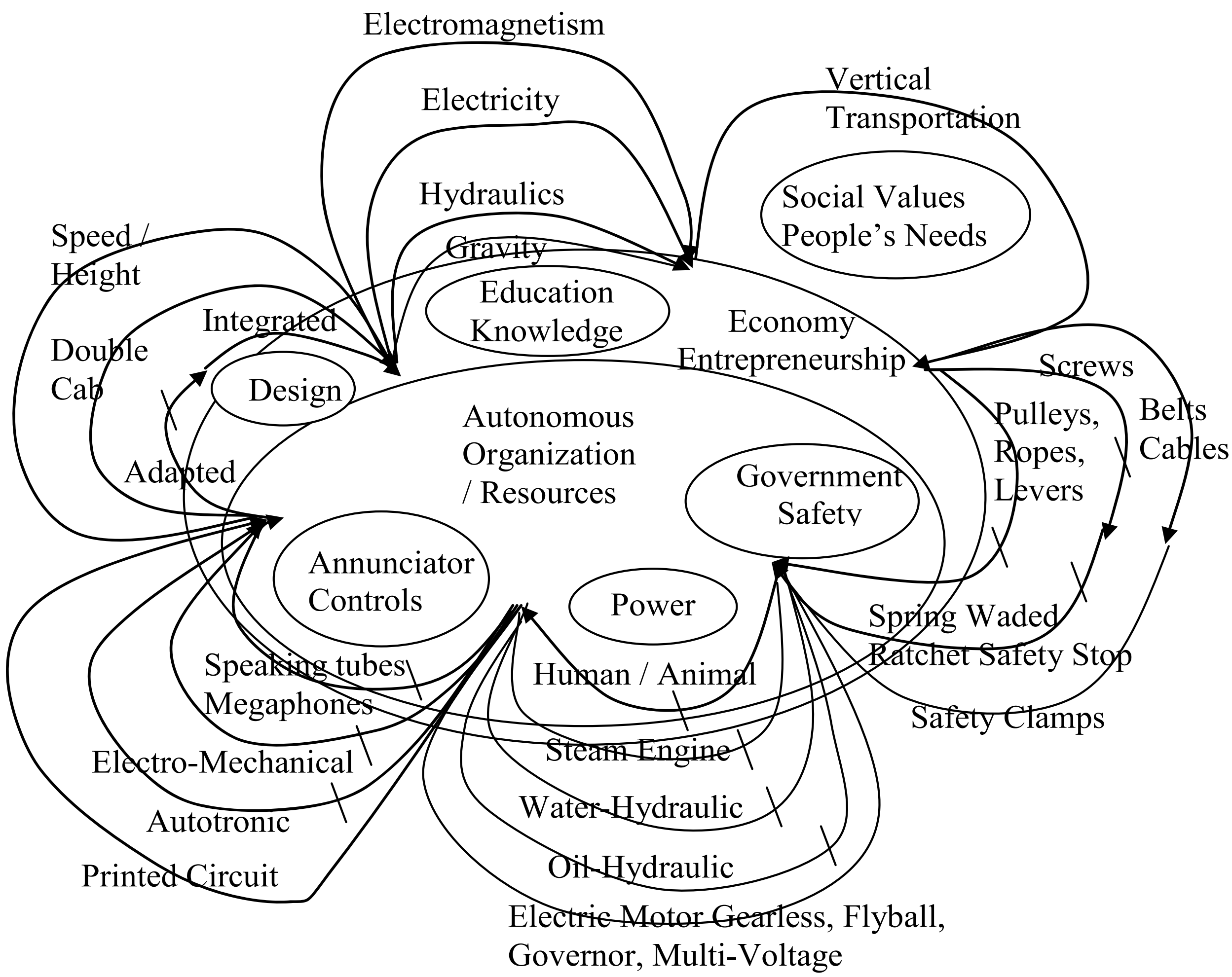


Fig. 4.13 Causal Look Analysis of Vertical Transportation, Elevator

Both the air conditioning and elevator systems development point to the elements, actors that typically influence change at this level of granularity and confirm the elements (actors) in the high-rise building and in the Industrial Revolution. The CLA of Elevator story (see *Fig. 4.15)*, highlights the role of autonomous organization and resources at the core of other elements of influence, namely economy / entrepreneurship, government (regulatory framework), education, social values and sub- sets of influence in the implementation of technologies such as safety, power, annunciator controls, and design.

The connection of the elevator with high-rise buildings and thus with building construction is through the population and demographic (affluence) that by their own nature is exponentialoid. In other words, the inventions and evolution of the air conditioning and the elevator are considered as a key element in the advent of the high rise which responds to a want for higher densities (perceived by developers and others as a need) and associated with (exponentialoid) increases in population and affluence.

4.6 CONCLUSIONS

In this chapter we have addressed, at a macro level, the issue of population growth which we have found to be exponentialoid (see Appendix I) in nature. The elements that have influenced this exponentialoid growth are complex and multiple. These elements were found through the analysis of Malthusian Positive Check proposition as well as his critics. The reason for addressing this MPC analysis are twofold: (i) population numbers drive building construction and (ii) the method for studying the dynamics between the multiple, complex elements of influence in regards to the population exponentialoid are transferable to building construction.

What we have found is that we can determine through historical thinking and the aid of

Causal Loop Analysis techniques the elements of influence in the industry as well as in building construction (through surrogates such as the high-rise, air conditioning and the elevator). Furthermore, those elements in themselves consists of multiple and complex sub-elements that exhibit a sense (i.e. arrival and evolution) which can be discerned in a time line.

Regarding the chosen typological characterization of the several IR, each IR exhibits a period in time of arrival and afterwards evolution into an exponentialoid that appears to reach a period in time of maturity heading towards decline. The next IR phase comes to the rescue and propels the general economy on its continual exponentialoid path directly affecting population growth, affluence and building construction. In summary the pre IR was based on tinkering, the I-IR was based on physics and energy; the II-IR on chemistry/molecular; the III-IR on electronics/atomic and the IV-IR on globalization/services/digital/nano technologies.

Regarding the elements of influence in building construction we found that they are also made of multiple and complex sub-elements with vectorial-like characteristic, such as origin, sense (direction), and magnitude that can be discerned against an exponentialoid.

Current approaches to sustainability, existing theories and practices, have no objective to tame an exponentialoid, the vision that originated them is reactionary, and the means proposed are fragmented. The industry needs to be convinced that a deeper understanding of complexity is needed where complexity is not reduced but in fact models are built based on the recognition of complexity. The implications of these findings for the next step of the argument is that we need to develop a theory of how multiple, complex elements of influence interact with an exponentialoid, the work of chapter 5.

CHAPTER 5
SUSTAINABILITY AS THE FORCE THAT TAMES AN EXPONETIALOID

In this chapter, we are going to address the definition of sustainability as the force that tames an exponentialoid, and a method for better capturing multiple and complex elements of influence of an exponentialoid. The point is that sustainability can not be looked at in isolation, (i.e. the building industry). Sustainability is not the property of an object but falls in the domain and has the characteristics and properties of a process.

The question that we are going to focus on is on how one vectorial characteristic, the sense or direction, affects an exponentialoid. What we have found is: (i) a method for understanding the Malthusian Positive Checks regarding the population exponentialoid is transferable and useful for a better understanding of the exponentialoids of other complex systems such as building construction industry, resource consumption, and emissions generation, and therefore (ii) (artificial) sustainability can be better understood as a force that tames and exponentialoid.

These insights, using an abstract/theoretical/philosophical approach, lead to the need of further work to determine the other vectorial components (direction and magnitude) of the elements and sub-elements of influence and thus better determine how multiple, complex forces influence an exponentialoid. The new conceptual/theoretical framework, for a new level of understanding of the construction industry is based on systems thinking and provides a base for followers to construct systems architecture and emerging models that do not reduce complexity but in fact are built on complexity.

What follows is a qualitative treatment of the forces that contribute to sustainability, acknowledging that a lack of matching empirical evidence places this work in the area of philosophy and not science. As a philosophy this work leads us to a framework for better understanding how to identify the general forces that affect sustainability, and the exponentialoid nature of sustainability in a post Forester era. Currently every domain and stakeholder is working from a limited world-view, although not necessarily arriving at the wrong instruments. These instruments and their contributions are significant; however the question remains if they are sufficient to tame the intended exponentialoid.

Chapter 6 will explore highly theoretical and speculative scenarios where the elements that influence the creation of an exponentialoid are also those that could tame it.

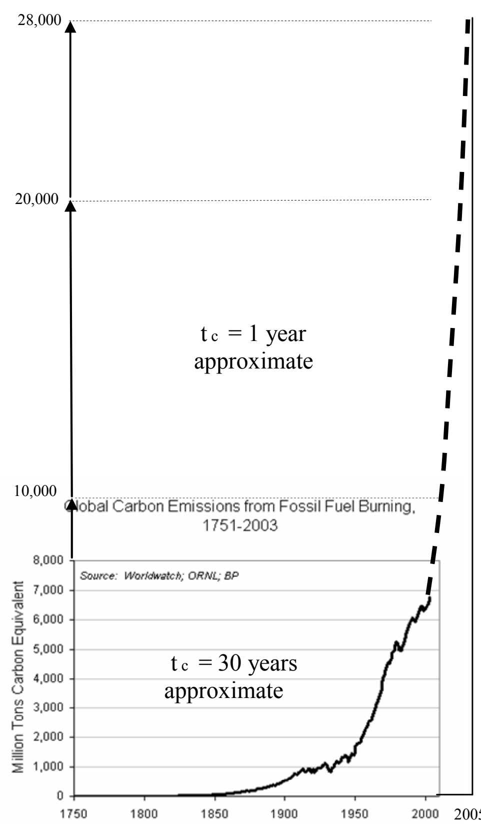


Fig. 5.1 Global Carbon Emissions from Fossil Fuel Burning 1750 - 2005

5.1 INTRODUCTION

Current understanding of sustainability, (see also Appendix K – Development of Sustainable concepts).

The term sustainability, in principle, is very old (see Beckmann 1785). Sustainability has come *in vogue* through the Brundtland report, defined as "development that satisfies the needs of the present without compromising the needs of the future (Brundtland Report). This view of sustainability is geared to bridge the generation gaps. Sustainability in this dissertation is approached from the input side (resource consumption) and from the output side (emissions generation) and therefore a property of the process.

From the input side, resource consumption, the current worldview understands sustainable as "renewable stock that grows over time according to its own biological dynamics" (Chichilnisky 1997) and its consumption is equal to or less than the stock. Utility in economic terms is dependent on the level of the renewable stock and the rate of consumption at any particular point in time. In this context, sustainability implies that we only use the increase and maintain a minimum reproductive stock.

Exhaustible resources require a significant reduction in consumption to give credence to 'sustainability' into the near and long term future. Two other assumptions, although not clearly articulated, are that the future will find substitutes (i.e. through technological advances), negating the consumption of resources into extinction, and that ways will be found to find more resources, more efficiently, and thus increase the time horizon when either depletion or substitution takes place. The assumption on irreproducible stock is that they are available in restricted quantities and that any increase will require a time horizon that is irrelevant for human planning purposes (Strebel 2005)

From the output side, unsustainable emission generation have no alternative than a significant reduction of emissions. However, the current levels of emissions have a prolonged effect on climate change that is difficult to ameliorate, even if emissions are drastically reduced in the short term (apparently, an unlikely event due to the exponentialoid characteristics).

Between these two issues, emissions generation is of greater concern. From 2003 when the graph shown in *Fig. 2.17*, the global carbon emissions from fossil Fuel burning has increased dramatically see *Fig. 5.1* an updated Fig. 2.17. (See Chapter 2 for underlying possible cuases and debate).

The unstoppable creation of built objects, the voracious uses of resources and the copious emissions are of an exponentialoid nature and are affecting the environment. There are multiple and complex forces that generate these exponentialoid increases. Sustainability, in our argument, looks at these forces differently from the current notion of sustainability. Sustainability is more than limiting growth to those products that can be grown indefinitely to match needs. This is an agrarian view of sustainability. Most products are artificially created manipulating resources that are technologically and economically as well as physically exhaustible and contributes highly with emissions during their life cycles. Therefore production and emissions sustainability requires a better understanding of the dynamics of exponentialoid growth and the forces, the multiple, complex elements that influence this rate of growth so that we can more acutely focus our resources to attenuate, ameliorate and eventually significantly reduce the exponentialoid growth.

One of the elements that influence the forces that generate the exponentialoid is the General Economy; with an 'inexhaustible' capital (currency) resource moves towards a contribution to value and utility (see *Fig. 1.4)*. However, historical analysis indicates that, besides the General Economy, there are other elements that need to be taken into account for a holistic worldview of the forces moving the current exponentialoids of resource consumption and emissions generation.

Chichilnisky (1997) is representative of the Forrester-Sterman worldview with an emphasis on the General Economy. She challenges the "overtaking criterion" and the "Ramsey criterion" as seriously incomplete by expanding on the Hotelling problem of the optimal depletion of an exhaustible resource. This position is explained in layman's terms through several Axioms: Axiom I require that the present should not dictate the outcome in disregard for the future: it requires sensitivity to the welfare of generations in the distant future. Axiom 2 requires that the previously mentioned welfare criterion should not be dictated by the long-run future, and thus requires sensitivity to the present. These axioms are based on an understanding and use of 'consumption vectors' which is an improvement on Forrester-Sterman's algorithmic understanding. However Chichilnisky 1997 formulations, as indicated, ignore for the moment the effects of population and affluence growth. The demographic changes towards increased consumption (affluence) at a global scale are not acknowledged. Ignoring population and affluence growth helps bind the problem, but at the expense of a complex, holistic worldview.

Chichilnisky 1997 poses an economist prime directive: "Humankind as an organism who seeks its overall welfare over time." From this prime directive position, the issue of a pertinent or relevant time horizon is approached: "our economic institution is grounded on finite horizons. Life on earth will certainly be of finite duration, although it is difficult to determine its final date. It is therefore important to determine whether sustainable preferences are merely an artifact of infinite horizons or are reasonable within a finite world." In other words, what is the time frame, the horizon, that we need to consider, (10, 100, 1000 or 10,000 years) when discussing a finite world?

Chichilnisky 1997 chooses a “sustainable preference, seen as a sustainable generalization, to infinite horizons of an intuitively appealing criterion for finite horizons.” This sustainable preference has two interesting properties according to Chichilnisky: (i) it is the “Green Golden Rule”[132] and (ii) as the finite horizon increases, the optimal solution of equal treatment (present and the future) finite horizon problem spends an increasing amount of time progressively closer to the limit of the path which is “optimal” according to sustainable preferences, (what she terms: the “turnpike” property). In other words, as time increases an optimal solution is reached, albeit at the margins of the limits of what can be considered optimal, that is: at the threshold of ‘critical.’

Her scenario is based on a definition of sustainability where increasing resource stock allows for an increasing horizon, informed by a relative declining rate of sustainable references (i.e. if and only if the discount rate falls –decreases- over time).

History of the Industrial Revolution, which overarches the General Economy, shows a pattern of an ever increasing rate of generation and consumption in all spheres of human endeavors, and this pattern has exponentialoid characteristics. The assumption that this growth rate (discount rate) will decrease over time is highly speculative and debatable. Borrowing Ellul’s 1954 dictum, “it is the gamble of the Economists.”

The following a brief short horizon observations on population, demographics, resource consumption and emissions generation: There are some indications of an ameliorating population rate of growth, but not in production, consumption, affluence and emissions. In terms

[132] Beltratti, Chichilnisky and Heal 1995: The Green Golden Rule is a stationary path which achieves the maximum utility level which is sustainable forever. This stationary solution lies on the curve on which consumption of the resources equal its renewable rate (quoted in Chichilnisky 1997).

of population growth the Total Fertility Rate appears to be decreasing and consequently population numbers and its exponentialoid could be tamed within the short horizon of a few generations. This brings other social issues, such as ageing population and its consequences to the General Economy, which may promote the reversal of the downward trend and encourage fertility[133]. In terms of a demographic increase in affluence, resources consumption, and emissions generations a decrease in the rate of growth is not in our horizons.

Chichilnisky 1997 expansion on the Hotelling case for exhaustible resources requires that the final stock be increasingly higher, the initial consumption lower and the initial shadow price be higher (Heal 1995). In other words, the "overtaking" criterion and its relative the "catch-up" criterion are at best incomplete. Her underlying premise and time horizon worldview is that "nobody alive today, not even their heirs, has a stake on the welfare of fifty generations into the future" Chichilnisky (1997).

[133] Portugal, Germany, Japan, and Russia are among the countries currently contemplating legislation that favours increasing birth rates.

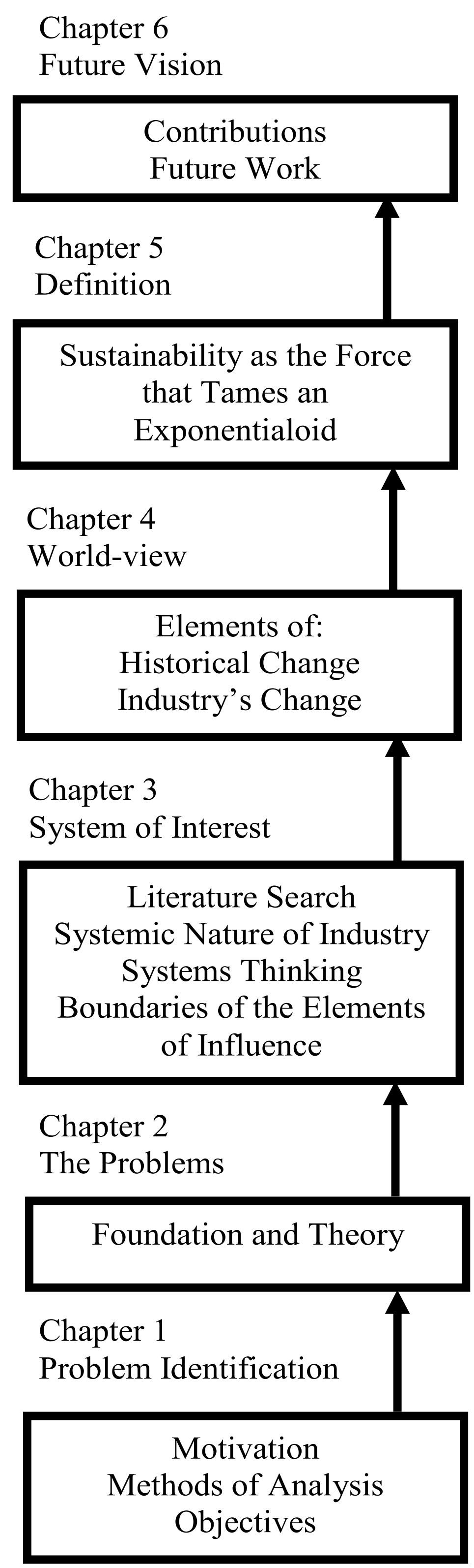


Fig. 5.2 "Intent Structure"
Chapters and Relationships

New understanding of sustainability

This dissertation relates the protection of the environment with the unstoppable creation of built objects and how can the building industry make a contribution. The question, re-phrased is: How are the exponentialoids of growth tamed so that this understanding represents a sustainable preference accounting for present and long-term future welfare? To do this we must be certain that all the major elements that influence the forces which create the exponentialoid growth are accounted for and that a rational method is derived, such as Chichilnisky 1997 did with her mathematical work on the General Economy in relation to consumption.

Fig. 5.2 is a recapitulation of the work in this dissertation based on Hitchins 1993 and frames the argument addressed in this chapter. We are now at the point that requires a greater in depth analysis of the relationship between sustainability and the exponentialoid.

5.2 THE CONCEPT OF SUSTAINABILITY AS THE FORCE THAT TAMES AN EXPONENTIALOID

In this chapter we develop and substantiate argument evolving from soft-systems to hard systems thinking (see *Figure 5.3*.) We have identified the issues surrounding population, affluence, consumption, and emissions growth. We have addressed the nature of the issues as being both exponentialoid and unsustainable. Furthermore we have identified that the issues are complex and have multiple elements of influence.

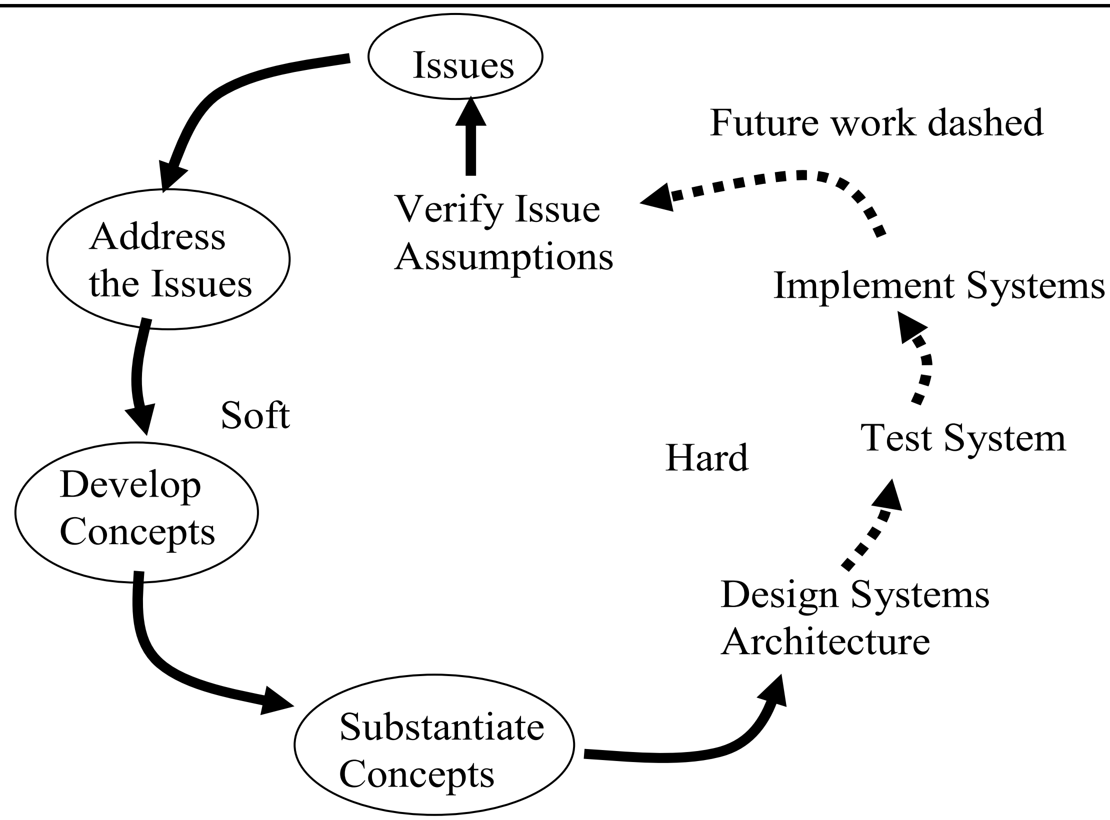


Fig. 5.3 Bridging from Soft to Hard systems of understanding (Based on Hitchins 1993)

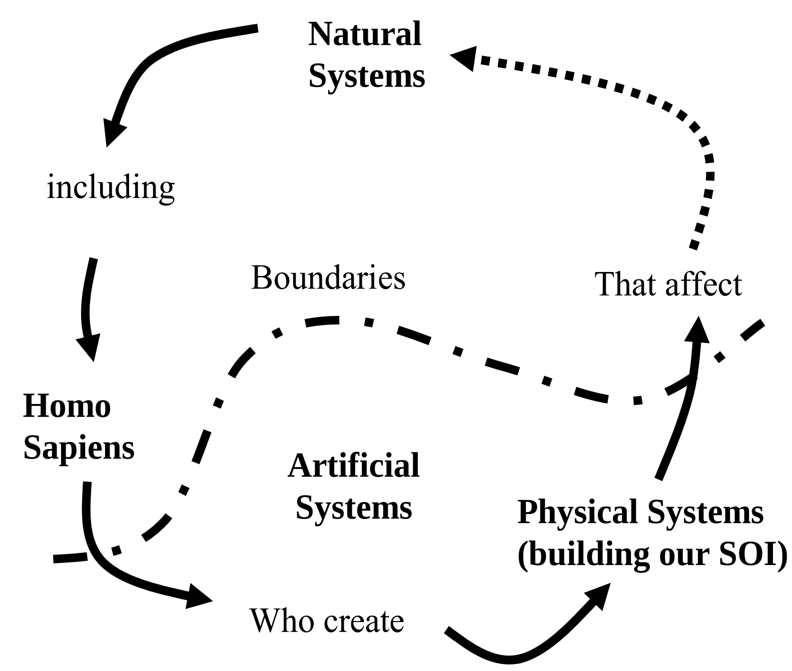


Fig. 5.4 Categorization of Systems (Adapted – dashed lines- from Checkland 1981)

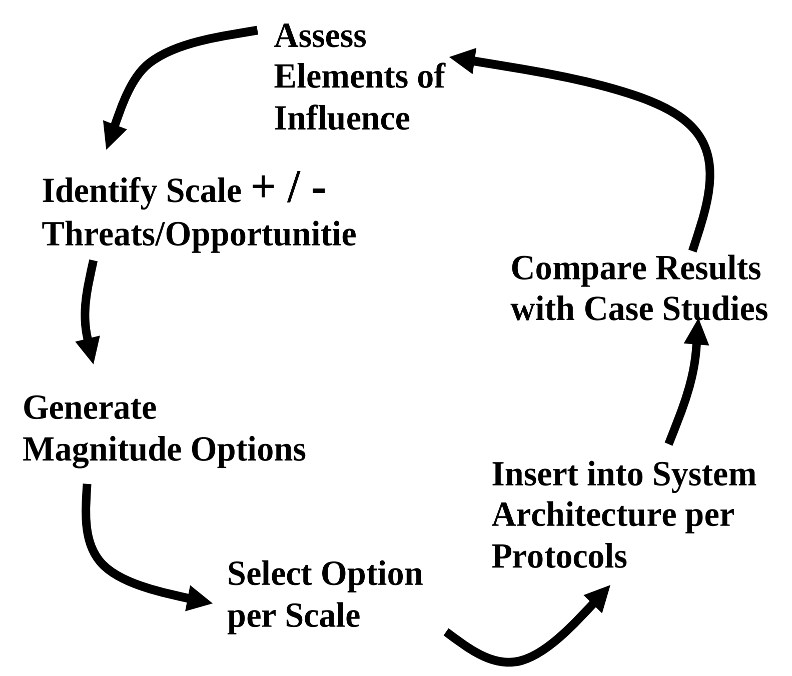


Fig. 5.5 Categorization of the Elements of Influence Decision circle

From analyzing MPC we have developed a concept of how some of the complex elements of influence have, through time, appeared on the scene. Next, through a system of positive checks developed by Malthus (1983) we have noted that there was a time when nature provided forces that maintained a sustainable condition and that through human intervention the sense of those forces changed, making the natural sustainability increasingly less influential and human intervention more influential. The result has been an exponentialoid population growth. This chapter substantiates the concepts preparing the way for future work: design of systems architecture, test the system and implement the system (see *Fig. 5.3*).

Fig. 5.4 is a categorization of the systems as envisioned in this dissertation (adapted form Checkland 1981). The boundaries between natural and artificial Systems are characterized. *Fig. 5.5* is a categorization of the elements of influence decision circle as envisioned for the systems architecture once the protocols are developed. This figure highlights that we have two interacting systems the natural and the artificial. Actually these are two meta-systems therefore we can expect a very high degree of complexity and an abundance of interstices according to Palmer 2003.

The system of Interest has been defined, as shown on *Fig. 5.7,* by the systems objective to tame an exponentialoid. The containing artificial and natural environments are also identified.

Regarding the System of Interest Table 5.1 identifies two prime directives, a strategy and the actors. This table is a matrix of two independent actors, Population and Building Construction with a vertical relationship as well as a horizontal relation based on the identified items. Chichilnisky's 1997 General Economy prime directive, "Humanity as an organism who seeks its own welfare over time" is implicitly contained in Prime Directive 1 and would be a redundancy.

Table 5.1 System	of Interest Organization	
Item	Population	Building Construction
Prime Directive 1	Survival of the Species	Shelter from Adverse Environment (needs)
Prime Directive 2	Propagation of the Species	Shelter and Comfort (needs and wants)
Strategy	Influence Total Fertility Rate	Demand: Anticipate needs and or react to wants for Shelter
Actors	Position Elements of Influence to “best” exploit fertility	Position Elements of Influence to “best” fulfill Demand

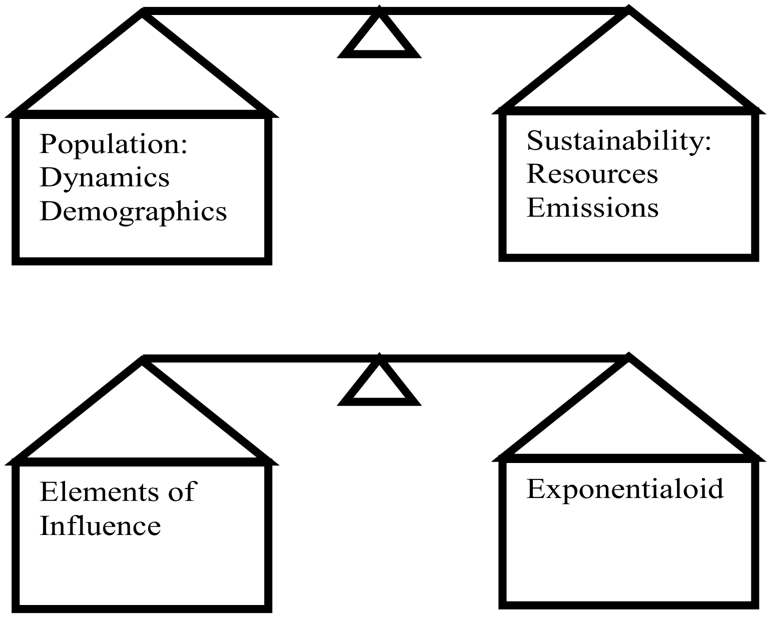


Fig. 5.6 Net Contribution Balance Using vectors (direction, sense –positive and negative and magnitude)

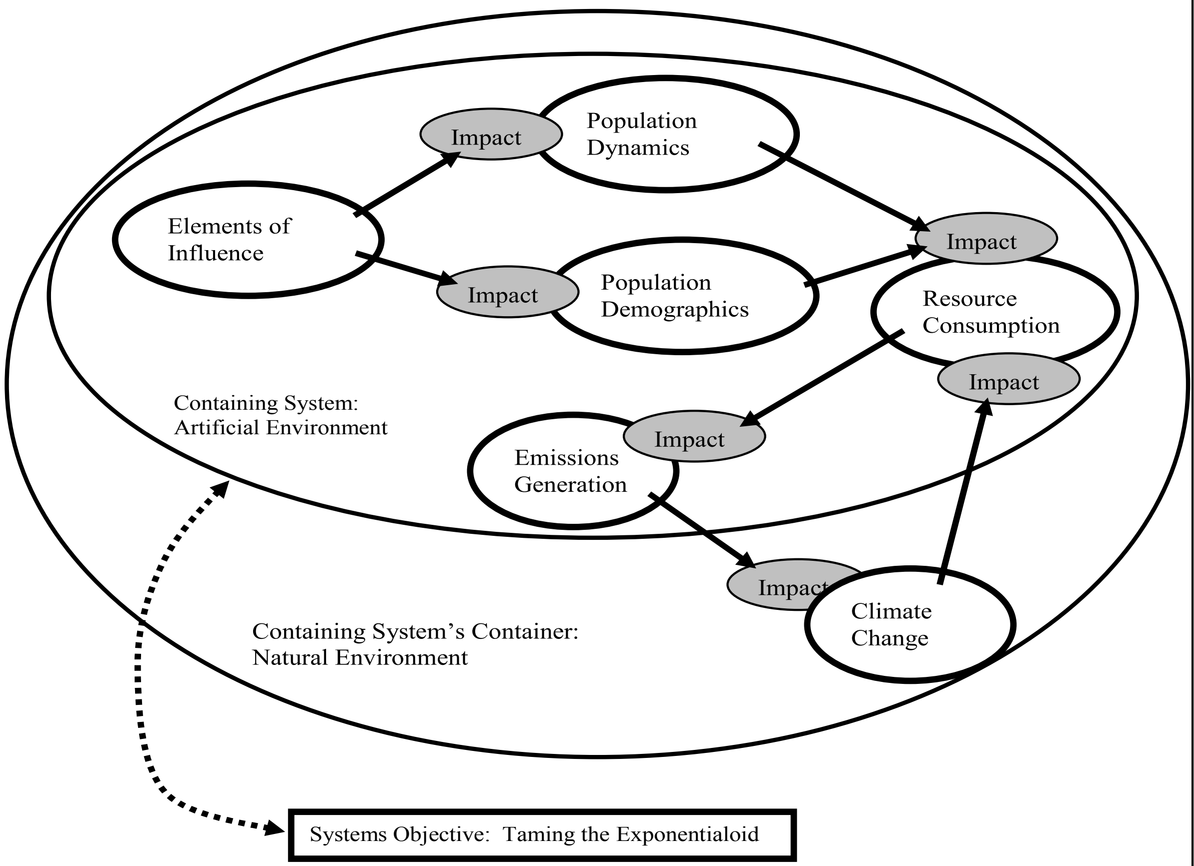


Fig. 5.7 System of Interest

The strategy and the threats in relation to environmental rate of change and consequent adaptation rate of change are shown in *Fig. 5.8 Statement of Strategy* (adapted from Hitchins 1993). This characterization of Strategy will be discussed in greater detail in Chapter 6. The concern of this statement of strategy with our argument is: If our current levels of emission have already initiated a long term wave of climate change (environmental rate of change), there will be an adaptive and reactive 'consequential adaptation rate of change' that Building Construction needs to be aware of, in its role of fulfilling the two prime directives (see *Fig. 5.8*).

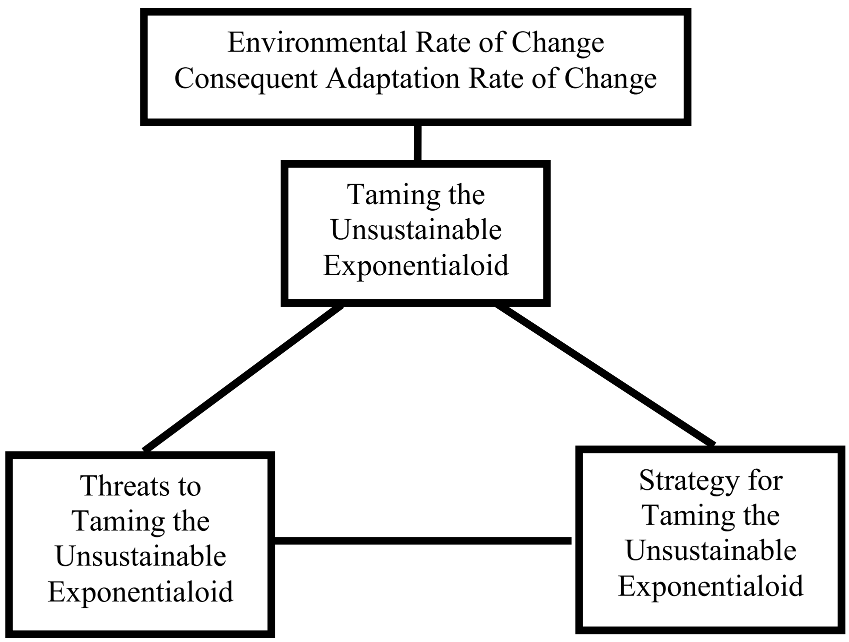


Fig 5.8 Statement of Strategy

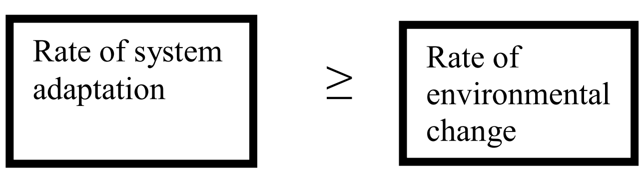


Fig. 5.9 Comparative Rates of Change

A net contribution balance using a vectorial methodology (adapted from Hitchins 1993) for the elements of influence is presented in *Fig. 5.6* where the population and affluence issues need to be balanced against resources and emissions through a balance of the elements that influence an exponentialoid growth rate. The elements of influence, in the argument of this dissertation, form a set called 'artificial sustainability.'

Identified threats to taming the unsustainable exponentialoid are shown in Table 5.2, Process Based Theory of Symptoms (adapted from Hitchins 1993). The argument is to identify the multiple and complex elements that influence our current inadequacy of controls and a mechanism for better understanding how these elements interact with the rates of growth that cause the exponentialoid.

Table 5.2 Process Based Theory of Symptoms

Item	**Excess**	**Inadequacy**
Population Dynamics	Numbers	Control of Total Fertility Rate
Population Demographics	Developing Needs/ Developed Wants	Control of: Total Fertility Rate & Rate of Affluence Growth
Resource Consumption	Needed for National and Organizational Survival Personal Wants, Desires	Control of Rate of Economic Growth
Emissions Generation	Existing & Growth	Control of Rate of Emissions

Fig. 5.10 shows the rules we are adopting in our argument. The basic premise is that the elements of influence are able to affect the rate of change. The assumption is that the elements of influence come from a certain capacity or potential for change that must be present whether it is actuated or not. Furthermore that capacity or potential needs to be of such magnitude that it can affect the exponentialoid.

For example, the current initiatives (Kyoto, EU 4/10 initiatives, Carbon Trading, LEED, BREEAM, GBTool, HQE^2R, etc) form part of elements of change although the argument has been made that, in themselves and collectively, do not have the capacity to affect exponentialoid growth. The other premise is that we can discern a 'universal' sustainability construct (how the elements of influence affect the exponentialoid) and that the nature of the vectors can be also discerned from a world-view and can be modeled and tested (see Appendix G).

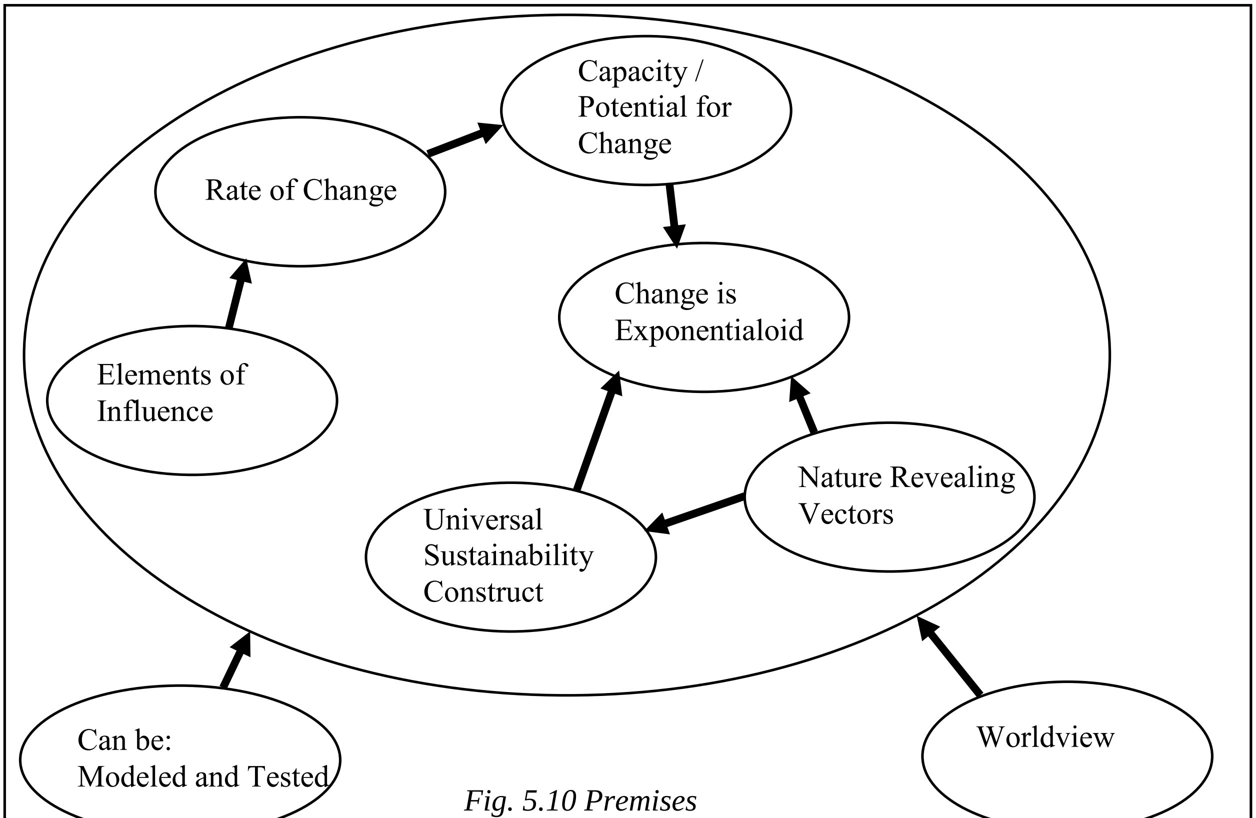


Fig. 5.10 Premises

Fig. 5.11 is a Causal Loop Analysis of the Systems of Interest (based on Hitchins 1993) indicating in bold the stronger lines of influence. This analysis shows the elements of influence that were first developed, one regarding Population and the other regarding the Industrial Revolution. Both are related to building construction, however building construction direct elements of influence (not shown in this *Figure*) were obtained independently through the analysis of the high rise, the air conditioning and the elevator.

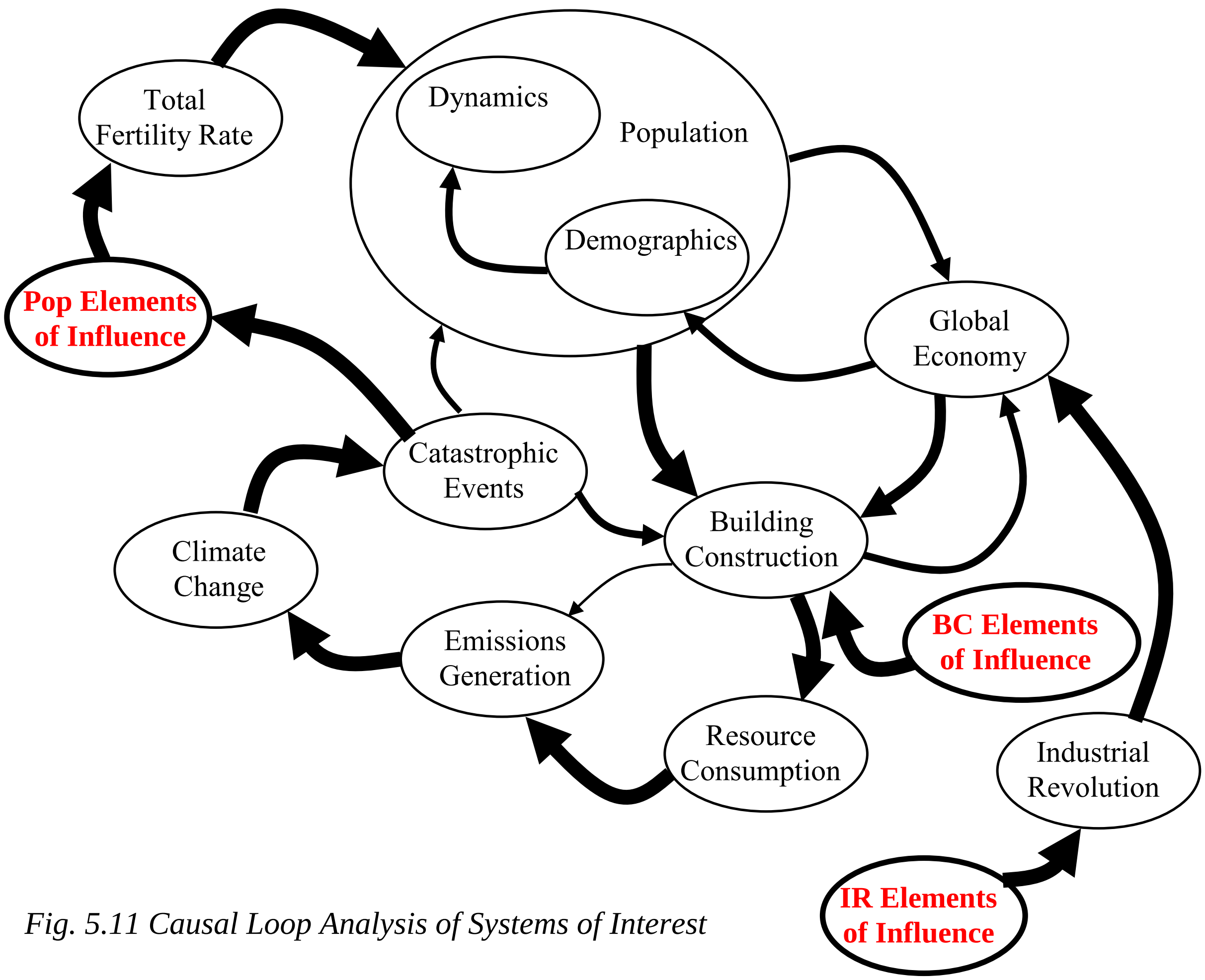


Fig. 5.11 Causal Loop Analysis of Systems of Interest

5.3 SYSTEM OF VECTORS, ASSUMPTIONS, PREMISES, RULES AND RELEVANCE ISSUES

Forces in nature manifests themselves through vectors and with a "coherent system of axioms, principles and concepts through which certain conclusions or deductions may be tested and compared with experience" (Adapted from Chichilnisky 1997 and García Bacca 1989). This section establishes the relevance issues, argues the principles, discuses the premises and proposes the assumptions in a coherent system (not of theory or quasi-theory but of analogue thinking and with heuristics) for analyzing multiple, complex elements that influence an exponentialoid. In our case with analogue thinking, not to be confused with a theory, we propose a set of assumptions, premises, principles and relevance issues as our set of rules, heuristics, to apply them.

Up to now, we have done different types of inquiry (historical, philosophical, methodological, epistemological, etc…) and now we conclude with a novel analogue based on our inquiry. This analogue identifies a vector field of changing sustainability forces. The hope of this dissertation and its legacy will be to have future research into these vectorial-like forces and be able to exploit this analogue in the architecture of systems with quantifiable forces.

5.3.1 Vectors as a force of change

Vectorial concepts are presented in Cartesian terminology using two or three coordinate systems[134]. We shall examine the vectorial characteristics of origin, direction which includes sense, and magnitude. The forces, in our system representation are vectorial-like; these are the

[134] Vector calculus or vector analysis has its origins in quaternion analysis formulated by J. Willard Gibbs. Three operations are important in vector calculus: gradient: measures the rate and direction of change in a scalar field; the gradient of a scalar field is a vector field; curl: measures a vector field's tendency to rotate about a point; the curl of a vector field is another vector field; divergence: measures a vector field's tendency to originate from or converge upon a given point. A fourth operation, the Laplacian, is a combination of the divergence and gradient operations. There are three theorems related to these operations: Gradient theorem, Stokes' theorem and Divergence theorem.

forces that induce change over time. We have identified the elements of the forces that influence change and propose that they can be characterized vectorially. We have identified the exponentialoid as the result of these forces and in our argument we propose that this exponentialoid is also a force that is vectorial in nature. However since we do not have the origin and magnitude of forces that created change (only the sense of its direction), and we have the resulting change, namely the exponentialoid, we use the result to analyze backwards what the forces could have been and in what direction. We present this effort in an analog thought pattern, that is, the rudiment of a method, not a theory, to identify a process of quantifying the exponentialoid and its related forces.

Origin

The point of origin in a static linear system can have the vectors superimposed or not. In this dissertation we assume that they all operate on the same node, for our qualitative study of the resulting net force. Origin carries the connotation that a vector may appear or disappear in the time-line construct. That is, the forces may be dormant or potential in nature and at some point in time they become active, dynamic. At the same time, forces that are active, dynamic, not only may change direction (sense) and magnitude but also may altogether cease to be active, dynamic, and revert back to a potential rather than a dynamic mode. In summary, this dissertation poses that through historical analysis (using CLA and other methods) the origin of forces and thus of vectors can be determined.

Direction (which includes sense)

Direction in Cartesian thinking is the location of a vector in relation to the coordinate system of space and time and in relation to other vectors and its sense. ‘Sense’ is the major focus of this dissertation. ‘Sense’ in the terminology of space/time is ‘now moving this way, and then moving that way'. In summary, this dissertation poses that through historical analysis (using CLA and other methods) the direction of forces and thus of vectors can be determined.

Magnitude

Magnitudes are presented in our argument conceptually with explanatory value. Magnitude carves out of space/form the properties of dimension, shape, substance and number. Magnitude is relegated for future research, as this may be the most complex vectorial element to uncover from a soft system on its way towards a hard system.

Based on the above framework we propose the following coherent system for analysis:

5.3.2 Heuristic assumptions, premises, rules and relevance issues:

Assumptions

Our analogue argument proposes two assumptions:

- <u>Assumption One</u> require that exponentialoid rate of growth is unsustainable because it is open to the infinite (Torricelli's acceleration diagram as quoted by Chichilnisky 1997)
- <u>Assumption Two</u> requires that the exponentialoid rate of growth is affected by multiple, complex, independent forces.

Rules

Our analogue argument proposes three rules:

- <u>Rule One</u> states that there are elements that constitute a necessary and sufficient set of accelerators of rate of growth called 'potential growth'
- <u>Rule Two</u> states that there are elements that constitute a necessary and sufficient set of inhibitors of rate of growth called 'growth modifiers'

- Rule Three states that there is a resultant vector force which is dynamic, bounded, and independent (see Principle 3), that is, the resultant of the sum of 'potential growth' and 'growth modifiers' that track the characteristics of an exponentialoid rate of growth.

Principles

Principles are laws or heuristics to guide a process. Our argument presents five guiding principles:

- Principle 1: There are two types of sustainability: Natural sustainability and artificial sustainability defined by the boundaries of nature and artificial creation
- Principle 2: Sustainability is a resultant vectorial force that acts upon an exponentialoid rate of growth
- Principle 3: The exponentialoid rate of growth is not a deterministic force but is constantly affected (modified) by the elements of influence
- Principle 4: Elements of influence are multiple and complex vectorial forces whose resultants are vectorial inhibitors (growth modifiers) and accelerators (potential growth)
- Principle 5: 'Exponentialoid' (as defined by García Bacca 1989) is used to express a growth curve that has a 'striving' towards the exponential in Cartesian terminology but differs from an 'exponential' in that it has multiple and complex sources and therefore its behavior is different than an exponential (consequentially Principle 3).
- Corollary to Principle 5: There must be a set of elements that influence sustainability with the potential capacity of taming the exponentialoid (Varignon & Forrester: "Effects are always proportional to their causes" which in a sense repeats Newton.)

Relevance issues:

We use relevance issues as a verification and justification to use analogue thinking at this stage of bridging the gap of knowledge between the identified elements of influence and how they behave and the resultant exponentialoid and its purported vectorial characteristics.

- Relevance issue 1: The hope is that a vectorial interpretation of the forces at work will manage to transcend its instrumental status to acquire explanatory value (Chichilnisky 1997).
- Relevance issue 2: The explanatory value is through universals which are highly symmetrical and perspicuous schema (Hitchins 1993 and Palmer 2003).
- Relevance issue 3: The forces in Lagrange's words (quoted by Mitcham 1994) are "the cause, whatever it may be, which impress or tends to impress upon the body to which it is supposed to be applied." In our case, the forces are real, multiple, and complex. The body (as the recipient of the action of the forces) is the resultant exponentialoid rate of growth that is an abstract construct of experience (Popper 1972).
- Relevance issue 4: Artificial sustainability's elements of influence, targets the rate of growth of an exponentialoid.

5.4 DERIVATION OF THE VECTOR ANALOGUE

The logic and reasoning are derived by analyzing how 'natural' and then how 'natural and artificial' sustainability's elements of influence affect the Total Fertility Rate manifested in an exponentialoid population growth.

5.4.1 Logic and reasoning of the arguments

We are going to first analyze the assumptions, rules and relevance issues based on MPC to showcase the logic and reasoning of the arguments. Afterwards, using the same method, we are going to apply the same logic, reasoning, and method to the elements that have influenced industrial rate of change during the IR. Lastly, we will use the same techniques on a composite list of elements of influence derived from the high-rise, air condition and the elevator to model how the elements of influence affect the rate of change of an exponentialoid.

Unfortunately, data does not readily exist that allows us to analyze how each of the elements of influence affects a particular industry or a sector or a trade such as air conditioning. Further study is required to scan historical records to discern points of origin, the direction, and the magnitude of the different inventions regarding construction.

5.4.2 The case of Population Growth

Assumption One requires that an exponentialoid is unsustainable. Population exponentialoid is a factor of rate of growth and population numbers (customarily expressed by an exponential: $N = N_o e^{rt}$, see Tables 1.1 and 1.2) at a given point in time (t, t + x). The theoretical extension of this exponentialoid growth into the future, towards a long time is unsustainable because it is open to infinity. However, as previously discussed, current Total Fertility Rate is decreasing (see *Fig. 2.2*) and although the base population number continues to increase, it is expected that in time the exponentialoid will be tamed. Further on we shall explore other assumptions, premises, rules, and relevance issues regarding this phenomenon.

Assumption Two requires that the exponentialoid rate of growth is affected by multiple, complex, independent forces. Malthus (1983) and his critics provide a list of elements that have influenced the population exponentialoid growth during the 'natural sustainability' Phase I (see *Fig.5.13* and *Fig. 5.2* and Table 5.3). These set of elements that have influenced the rate of growth during the natural sustainability have also influenced the exponentialoid rate of growth during Phase II and III. The set is considered in our argument as forces that are multiple, complex and independent[135]. These elements of influence as forces are vectorial in nature, according to our argument, thus possess origin, direction (sense) and magnitude.

Rule One states that: there are elements that constitute a necessary and sufficient set of accelerators of rate of growth called 'potential growth.' In the case of population this set is the Total Fertility Rate (TFR) and is arrived from the national, regional or local Fertility Rates at a period in time. This TFR has been declining in time as shown in Fig. 2.2. Extrapolating the curve backwards we can see that the TFR was significantly higher during Phase I – higher than 14 (up to ca. 1700); in Phase II – approximately 14 (1700 – 1900); decreasing to approximately 6 in Phase III (1900 – 2000); and further decreasing to approximately 2.1 or below in Phase IV.

Rule Two states that: there are elements that constitute a necessary and sufficient set of inhibitors called 'growth modifiers' which in this case is the list of elements of influence from the MPC. Although we do not know the magnitude of each of these elements, our current theory is mainly concerned with the change in 'sense' of these elements: The change in direction or 'sense' from a positive to a negative effect on 'natural sustainability'. For example, the change in climate (from what is called the Maunder Minimum - see Appendix F) is attributed with an increase in agriculture that allowed an increase in population by negating some of the detrimental (by human standards) effects of natural sustainability. But early death by plagues, birthing, wars etc. continued to decrease population during Phase I. Advances in agriculture production, hygiene, medicine, urbanization, and education of the population among others began cutting on the death rate in Phase II. In conclusion, the forces of that the elements of influence exerted as part of artificial intervention were sufficient to offset a declining TFR by a lower mortality rate

[135] We follow García Bacca's (1989) logic that swimming, canoeing, sailboat, steam engine ships, and nuclear power vessels are not consequential but independent inventions.

resulting in an increased base of population numbers depicted by the growth at the base of the exponentialoid in *Fig. 5.12*.

Rule Three states that: the vector rate of growth (acting on population) is the resultant vector from ‘potential growth’ – accelerator, and ‘growth modifier’ – inhibitor vectors (see *Fig. 5.14)*. In this case accelerator stands for the fertility rate of growth forces while inhibitor stands for the forces that have either an increasing or decreasing effect on the accelerator thus a growth modifier. Because of the convention used is counter intuitive, the wording lends to confusion, for example advances in medicine are positive (in terms of human experience) thus we associate it with the concept of acceleration of population. In the Malthusian Positive Checks convention, medicine as a ‘positive’ modifies mortality rate (by decreasing it) thus ‘inhibit’ mortality. The net effect of an inhibitor is the opposite of its meaning, a net increase in population number.

Notes about the following figures: As previously mentioned, vectorial magnitudes have not been determined at this time. *Fig. 5.12* establishes the three vectors (darker arrows) we have selected for examining Phases I (*Figs. 5.14; 5.16; 5.17*), II (*Figs. 5.15; 5.18; 5.19*) and III (*Figs. 5.20; 5.21; 5.22*).

Fig. 5.13, shows relations (stronger in bold) of the elements of influence, with sign convention, using Close Loop Analysis techniques (adapted form Hitchins 1993) to a list of Malthusian Positive Checks. Interestingly, the bubonic plague, a catastrophe, is credited with ending feudalism; starting a concerted campaign of hygiene; sewer and potable water infrastructure construction, education, and the start of technological advances (see Appendix J.) This crisis in Western Europe sits at the threshold of the Industrial Revolution. Crisis has been defined as the threshold of drastic change.

Table 5.3: Malthusian
Positive Checks &
Elements of Influence

Influence/Phase	**I**	**II**	**III**	**IV**
Environment Climate change	+/-	-	-	-/+?
Social Urbanization	+	+/-	-	-/-
Economic Needs to Wants	+	+/-	-	-/-
Technology Infrastructure	N/A	+/-	-	-/-
Government Wars	+	+/-	-	-/+?
Education	+	+/-	-	-/-
Agriculture	+	+/-	-	-/-
Medicine - Hygiene/Disease/ Pandemics Pestilence	+	+/-	-	-/+
Resources	N/A	N/A	N/A	-/+?
+ Totals	7	7	0	3
- Totals	1	8	8	9

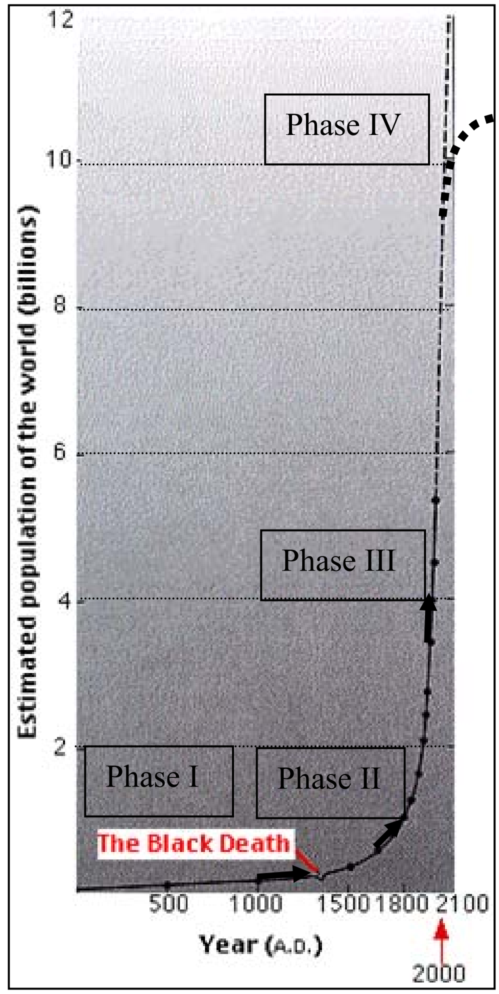


Fig. 5.12 Predicting Population Size
http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/P/Populations.html
(adapted)

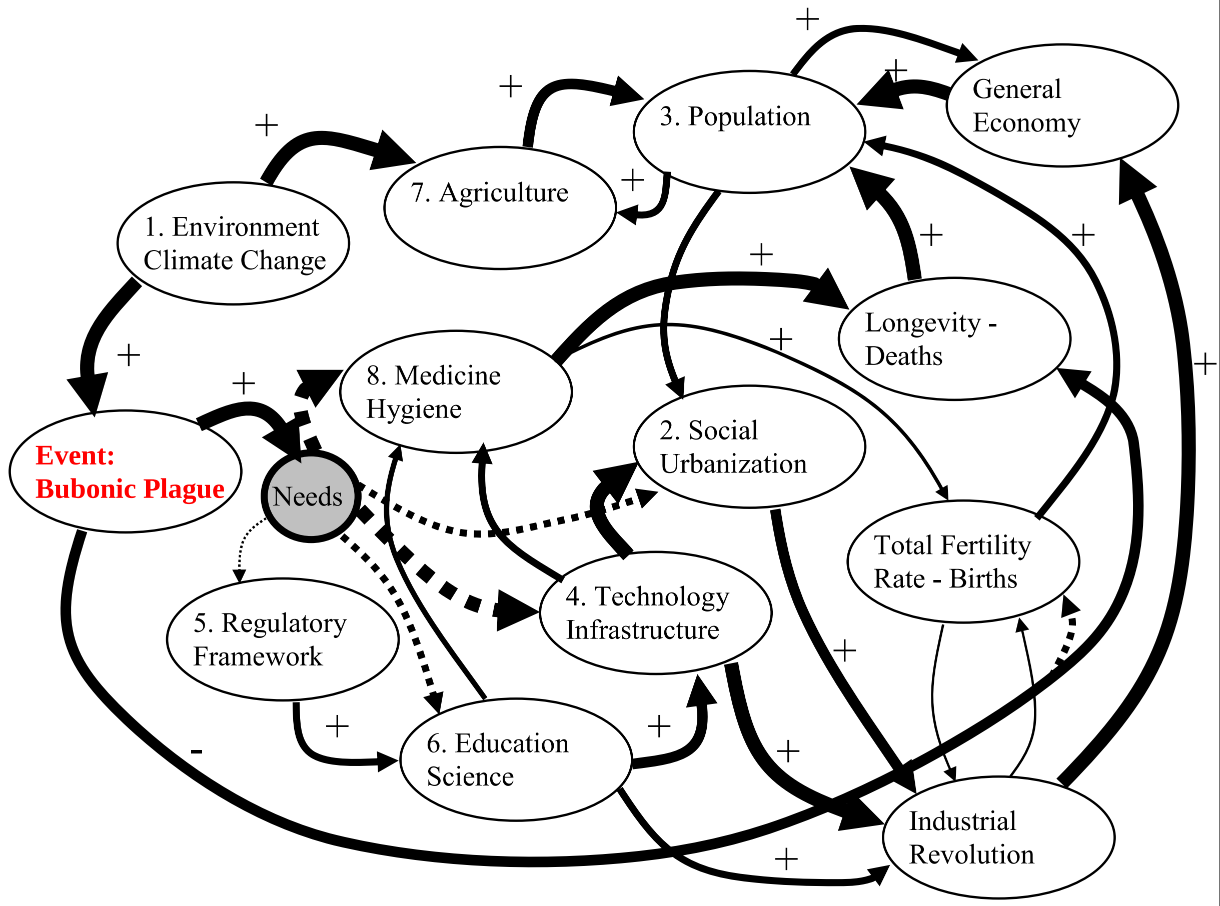


Fig. 5.13 Causal Loop Analysis of Malthusian Positive checks

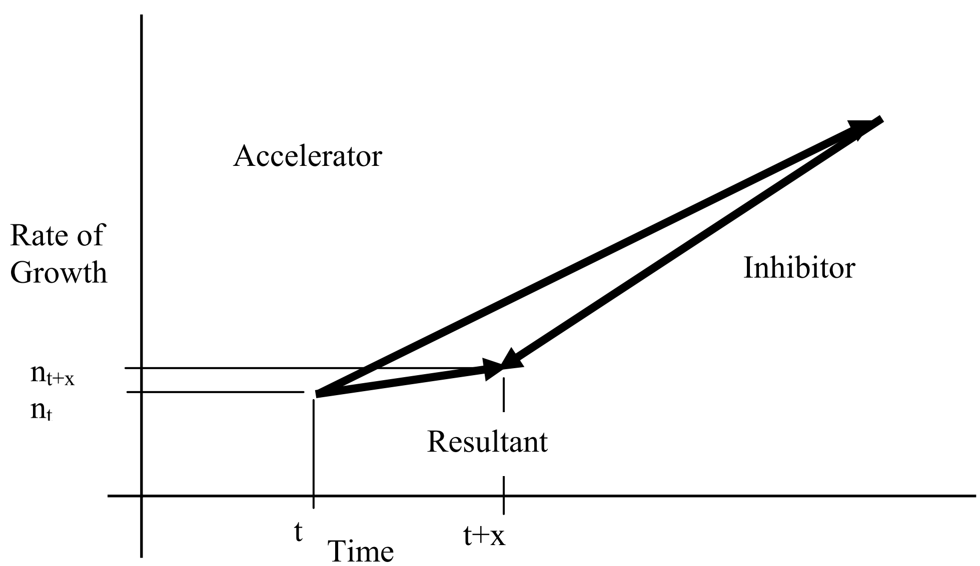


Fig. 5.14 Rate of Growth Vectorial Components (Phase I)

In Phase I the accelerator increases (higher fertility) as recorded in the historical documents, due to the early stages of the IR. In contrast, for example Phase II, the accelerator vector the Total Fertility Rate is less than in Phase I (per *Fig. 2.2*) but the inhibitor (mortality rate) has decreased even more radically due to further advances in medicine, hygiene, urbanization, better agricultural production methods, the effects of the Industrial Revolution etc. as shown in *Fig. 5.15.*

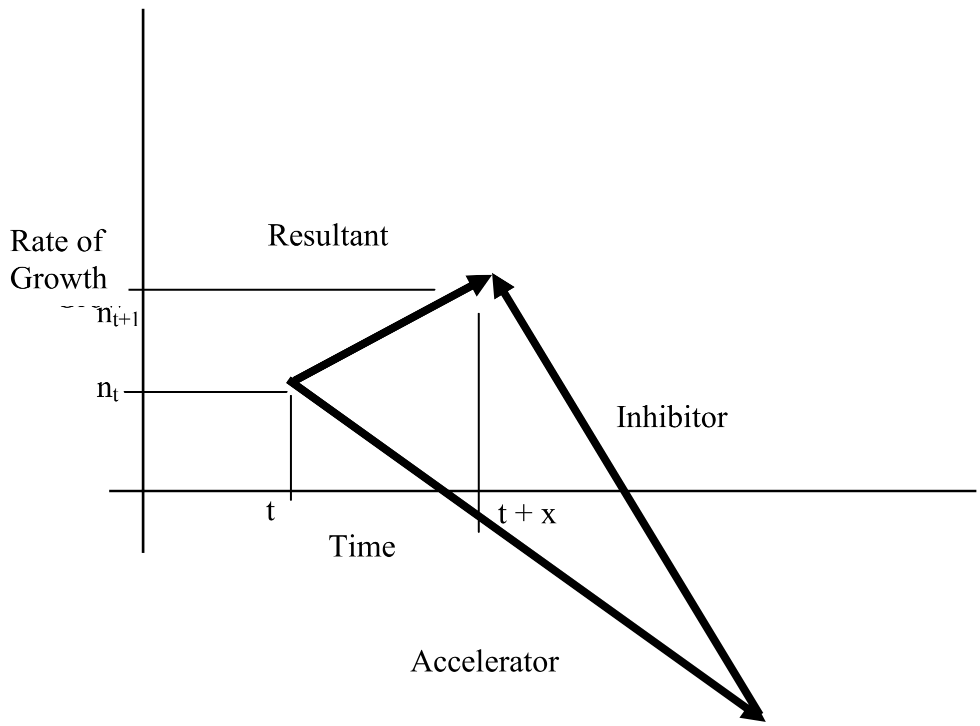


Fig. 5.15 Rate of Growth Vectorial Components (Phase II)

Principle 1 states that there are two types of sustainability: Natural sustainability and artificial sustainability defined by the boundaries of natural and artificial manipulation. Natural sustainability is interpreted in our argument to be the forces that naturally produce a fertility rate as well as a mortality rate. Artificial sustainability on the other hand is composed of those forces that can be attributed to human intervention following the prime directives, such as increasing agricultural production, increasingly effective and available medicine, hygiene, improvements in urban living conditions etc.

Principle 2 states that sustainability is a resultant vectorial force that acts upon an (otherwise) exponentialoid rate of growth. For example the accelerator vector is composed of the Fertility Rate. In our argument we take the Fertility Rate numbers that are currently available along with the assumed characteristic that this rate is decreasing over time. The forces that make fertility as well as mortality rate decrease or increase are attributed to human intervention, in this case, the elements of influence from the MPC. In the current stage of development of our argument, we have assumed a direction and a magnitude in order to study the significance of a change in “sense’.

E1. Environment Climate change	+/-
E2. Social Urbanization	+
E3. Economic Needs to Wants	+
E4. Technology Infrastructure	N/A
E5. Government Wars	+
E6. Education	+
E7. Agriculture	+
E8. Medicine - Hygiene/Disease/ Pandemics Pestilence	+
E9. Resources	N/A

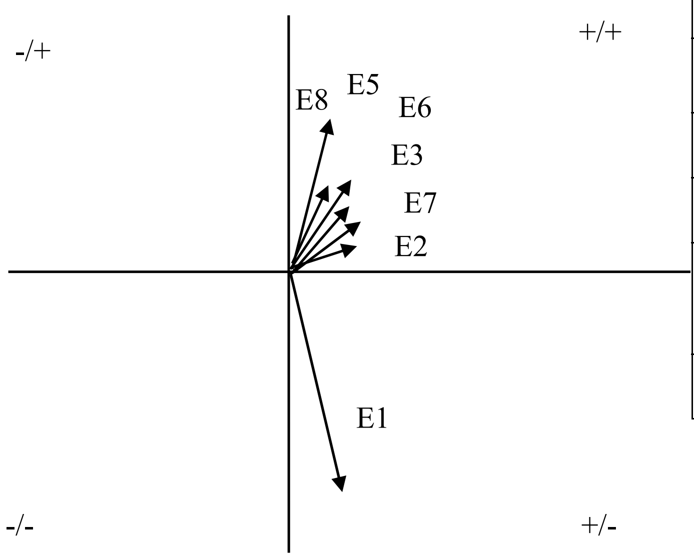


Fig. 5.16 Elements of Influence of Inhibitor Vector (Phase I example)

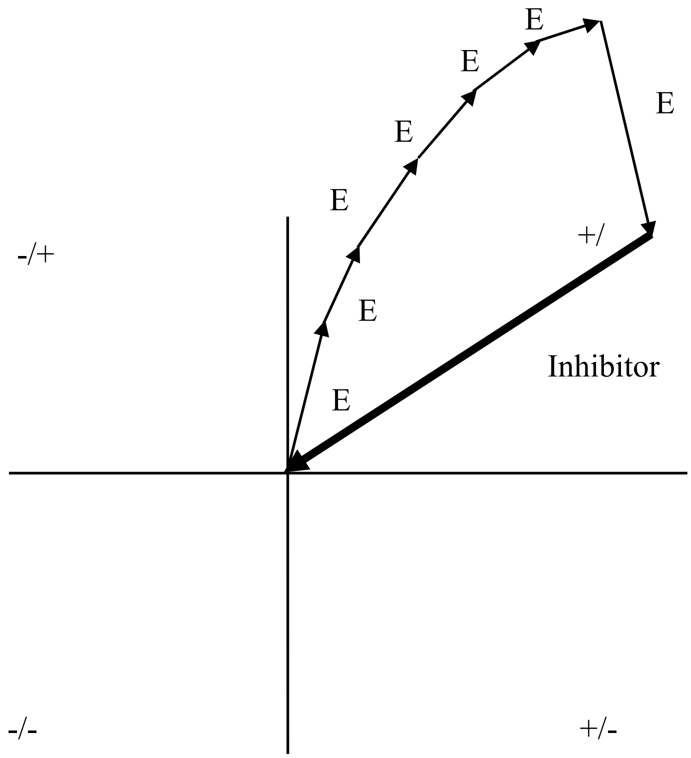
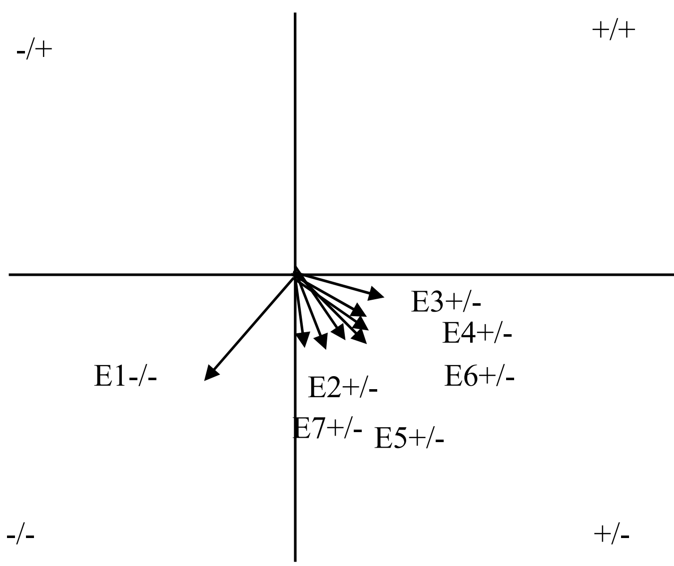


Fig. 5.17 Resultant Inhibitor Vector (Phase I example)



Influence/Phase	I	**II**
E1. Environment Climate change	+/-	**-**
E2. Social Urbanization	+	**+/-**
E3. Economic Needs to Wants	+	**+/-**
E4. Technology Infrastructure	N/A	**+/-**
E5. Government Wars	+	**+/-**
E6. Education	+	**+/-**
E7. Agriculture	+	**+/-**
E8. Medicine - Hygiene/Disease/ Pandemics Pestilence	+	**+/-**
E9. Resources	N/A	**N/A**

Fig. 5.18 Elements of Influence of Inhibitor Vector (Phase II example)

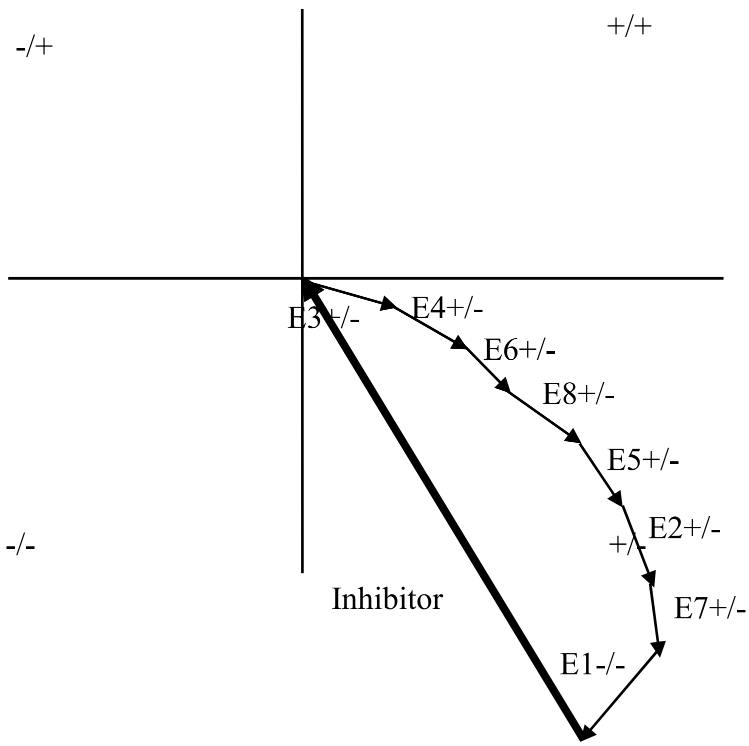
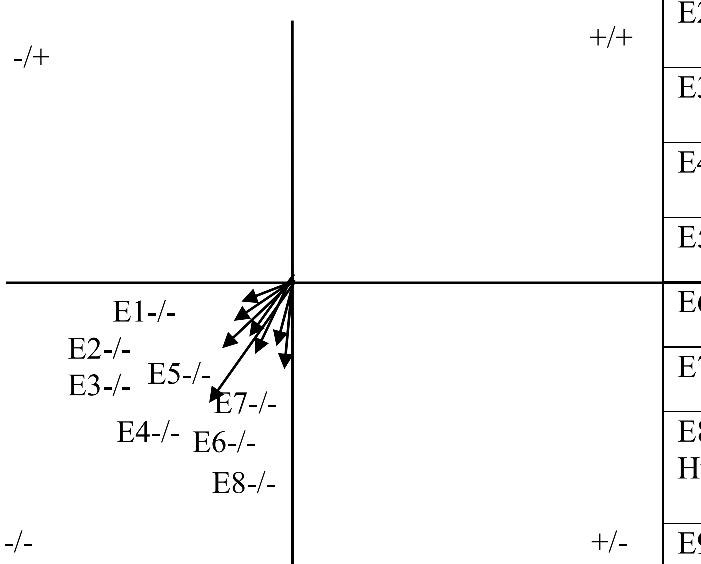


Fig. 5.19 Resultant Inhibitor Vector (Phase II example)



Influence/Phase	I	II	III
E1. Environment Climate change	+/-	-	-
E2. Social Urbanization	+	+/-	-
E3. Economic Needs to Wants	+	+/-	-
E4. Technology Infrastructure	N/A	+/-	-
E5. Government	+	+/-	-
E6. Education	+	+/-	-
E7. Agriculture	+	+/-	-
E8. Medicine - Hygiene/Disease/ Pandemics	+	+/-	-
E9. Resources	N/A	N/A	N/A

Fig. 5.20 Elements of Influence of Inhibitor Vector (Phase III example)

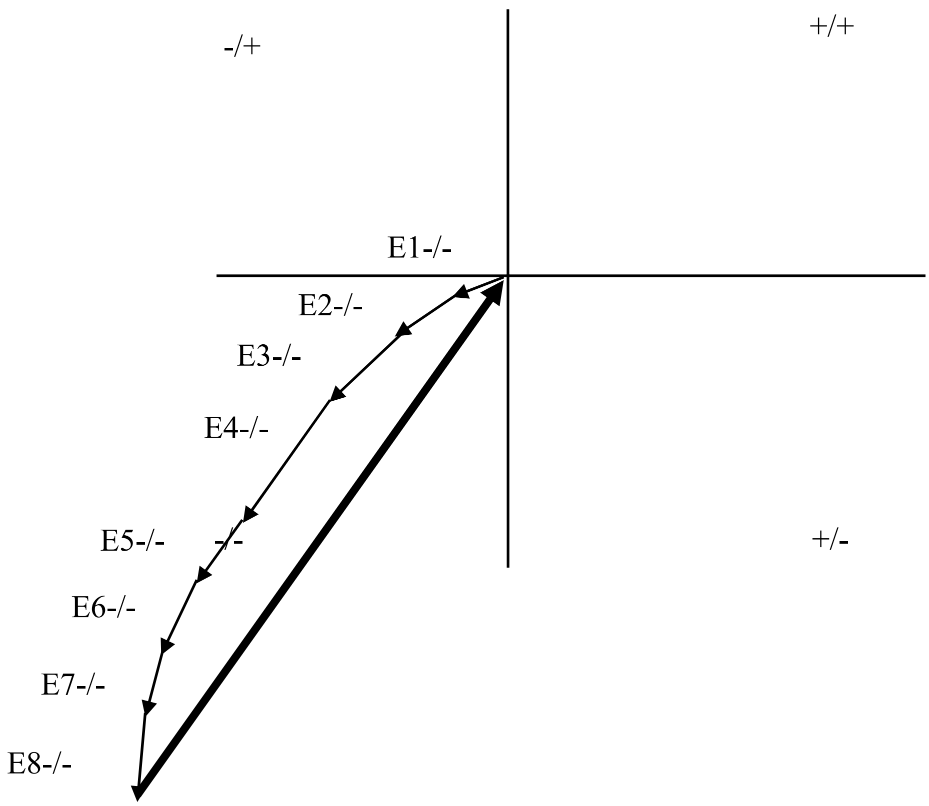


Fig. 5.21 Resultant Inhibitor Vector (Phase III example)

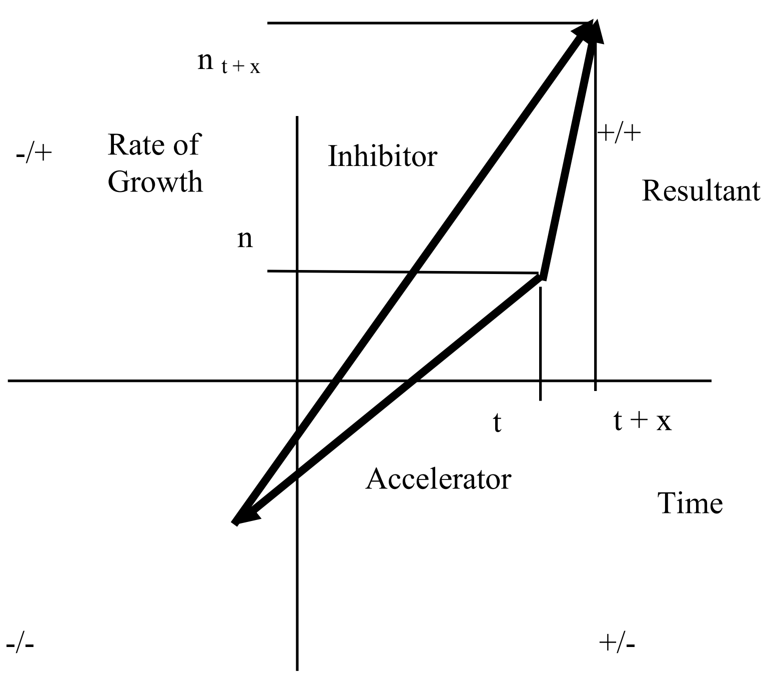


Fig. 5.22 Rate of Growth Vectorial Components (Phase III example)

Principle 3 states that: the exponentialoid rate of growth is not a deterministic force but is constantly affected (modified) by the elements of influence. What this means is that from a "t" time to the next "t + x" although trends tend to smooth out the rate of growth, the multiple and complex elements of influence may change direction or magnitude sufficiently to alter a deterministic course.

Principle 4 states that: Elements of influence are multiple and complex vectorial forces whose resultants are vectorial inhibitors and accelerators. The above examples showcase in *Figs. 5.17; 5.19; 5.21* how the elements of influence vectors (with assumed magnitude and direction) coalesce in resultant vectors.

Principle 5 states that: 'Exponentialoid' is used to express a growth curve that has a 'striving' towards the exponential in Cartesian terminology but differs in that it has multiple and complex sources. This principle is based on the work of García Bacca (1989) and others.

Relevance issue 1: Hopes that a vectorial interpretation of the multiple and complex forces at work that up to now can be discerned through soft-systems methodology, will manage to transcend its instrumental status and acquire, through both soft and hard system methodologies an explanatory value. We are cognizant that this will be realized more fully when the issue of vectorial magnitude is resolved through future work.

Relevance issue 2: Acknowledges that in order to reach explanatory value, a 'universal' presentation needs to be made. However the concept of 'universal' in our heuristic world is interpreted to be bounded between the world of the micro and the world of the in macro which each one has a set of universal constructs. The schema for interpreting the universal concept that 'artificial sustainability is the force that tames an (unsustainable) exponentialoid' appeals to logic in need of explanatory argumentation. Our argument is based on vectorials which have been found to have universal explanatory value in other disciplines (see Appendix I).

Relevance issue 3: The forces 'are the cause, whatever it may be, which impress or tends to impress upon the body to which it is supposed to be applied.' In the case of population growth, our argument is based on the forces that the elements of influence generate (through accelerators and inhibitors) affecting the rate of growth that along with population numbers (N_o) have created an exponentialoid ($N = N_o e^{rt}$). Our argument states that these forces (e^{rt}) are real, multiple, complex and independent, and can be interpreted in vectorial terminology.

Relevance issue 4: States that 'artificial sustainability's elements of influence target the rate of growth of an exponentialoid. Therefore, if the exponentialoid is to be tamed (that is, its unsustainable characteristic, the tendency towards the infinite) the elements of influence need to significantly affect the rate of growth. In our current example all the elements of influence must conspire to affect the rate of growth (e^{rt}), as it appears to be the case depicted in Phase IV.

5.4.3 The case of the Industrial Revolution and Emissions Generation

Assumption One requires that an exponentialoid is unsustainable. The General Economy, based on currency appears to be an exponentialoid without physical boundaries (see *Fig. 1.4*), that is, an inexhaustible resource. Likewise increase in global affluence, acquisitive power is rising without apparent physical boundaries. Resource consumption and emissions generation are affected by the General Economy, Population Growth and Global Affluence which as we have seen are forces with exponentialoid characteristics. As we have seen there is considerable debate on whether or not resources have boundaries, have limitations. However, logic indicates that consumption open to infinity is not sustainable. In contrast, there appears to be a gathering consensus among stakeholders that the exponentialoid growth of emissions needs to be tamed.

An exponentialoid growth of emissions tending towards infinity is unsustainable (see *Fig. 5.23*, dark lines are the vectors selected for examination). Otherwise, if emissions growth continues on an exponentialoid trend and affect climate change, the rate of human adaptation will have to match or be greater than the rate of environmental change (see *Fig. 5.9*).

The argument in Axiom 2 states that the elements that have influenced the IR found in Table 5.4, are the same that have influenced the Global Carbon Emissions.

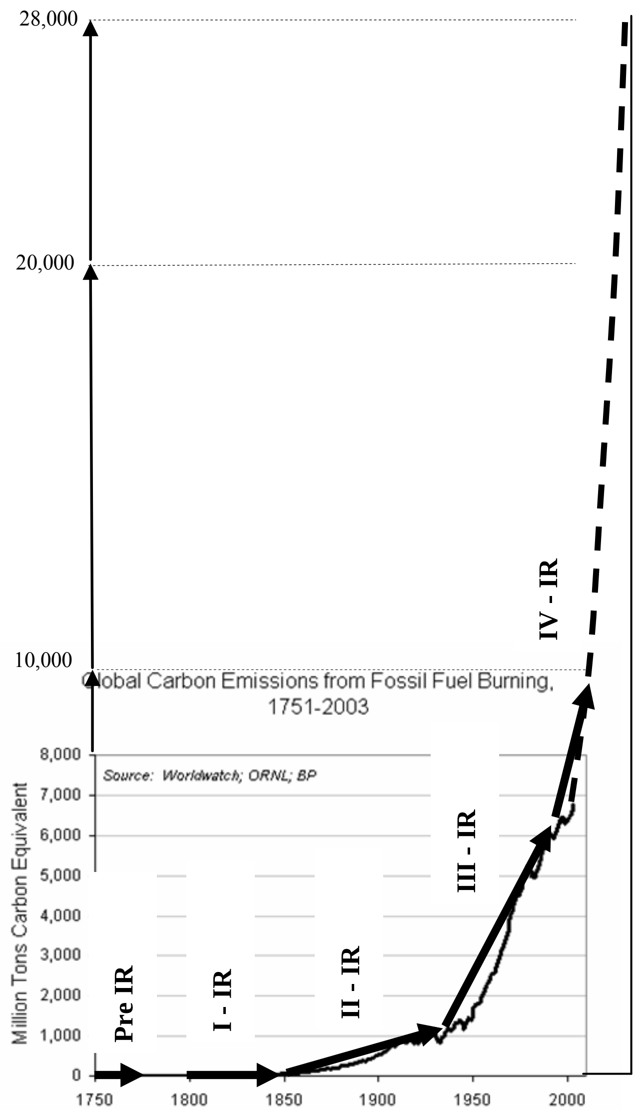


Fig. 5.23 Global Carbon Emissions and The Industrial Revolutions

Item	Table 5.4 The Industrial Revolution **Elements of Influence/Phase**	**Pre IR 1100-1700**	**I IR 1700-1850**	**II IR 1850-1940**	**III IR 1940-1990**
1	People Population Dynamics Demographics	+	+	+/-	-
2	Climate	+/-	+/-	-	-
3	Social Attitudes Cultural Legacy	+	+/-	-	-
4	Entrepreneurship	+	+	+/-	-
5	Organizational	+	+/-	-	-
6	Technology	+	+/-	-	-
7	Inventiveness Tinkering to Innovations	+	+	+/-	-
8	Regulatory Framework	+/-	-	-	-
9	Economy National Multi-national	+	+	+/-	-
10	Education Knowledge transfer	+	+/-	-	-
	+ Totals	10	9	4	0
	- Totals	2	6	10	10

Assumption Two requires that the exponentialoid rate of growth of resource consumption and emissions generation is affected by multiple, complex, independent forces. The Industrial Revolution has propelled civilization towards the current levels of resource consumption and emissions generation. Therefore we look into the elements that have influenced the IR for a set of multiple, complex and independent forces. As previously mentioned, between resource consumption and emissions generation openness towards the infinite, the later appears to be more critical and is used in this example.

Rule One states that there are elements that constitute a necessary and sufficient set of accelerators of rate of growth called 'potential growth.' Unlike the example on population, there is not a growth rate number such as Total Fertility rate that can be used, however historical data of the growth in emission generation is available and the exponentialoid is taken at face value for the purpose of this example. Because of time constraints and the priority of emissions we have selected emissions generation exponentialoid as basis for this example. Behind the emissions growth the theorem requires a set of necessary and sufficient elements. This set is found in Table 4.2 with the caveat from the next theorem. (See *Figs. 5.24 Pre-IR; 5.27 I-IR; 5.30 II-IR; 5.33 III-IR.)*

Rule Two states that there are elements that constitute a necessary and sufficient set of inhibitors of rate of growth called 'growth modifiers.' Table 4.2 was generated by analyzing writings from multiple experts of the Industrial Revolution form the set that can be either accelerator or inhibitor. The logic implored is based on the observation that as time progresses, the IR not only spread globally, affecting the General Economy, and generally caused increases in affluence, resource consumption and emissions generations. (See *Figs. 5.25 Pre-IR; 5.28 I-IR; 5.31 II-IR; 5.34 III-IR.)*

Rule Three states that there exists a resultant vector force which is dynamic, bounded and independent that is the resultant of the sum of 'potential growth' and 'growth modifier' that tracks the characteristics of an exponentialoid rate of growth. (See *Figs. 5.26 Pre-IR; 5.29 I-IR; 5.32 II-IR; 5.35 III-IR.)*

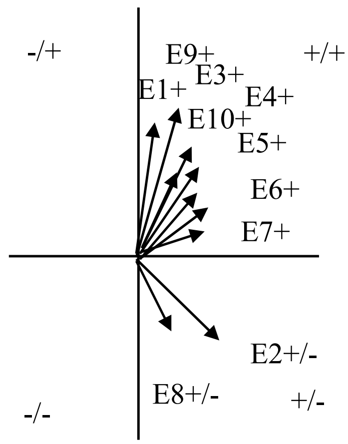


Fig. 5.24 EoI of Inhibitor Vector (Pre-IR)

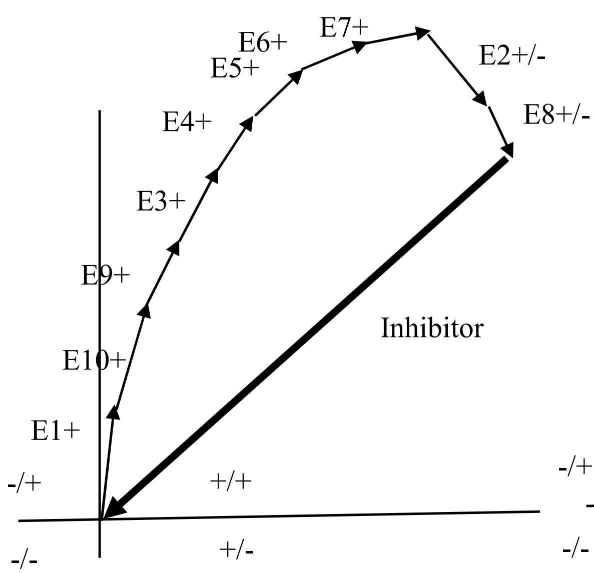


Fig. 5.25 Resultant Inhibitor Vector (Pre-IR)

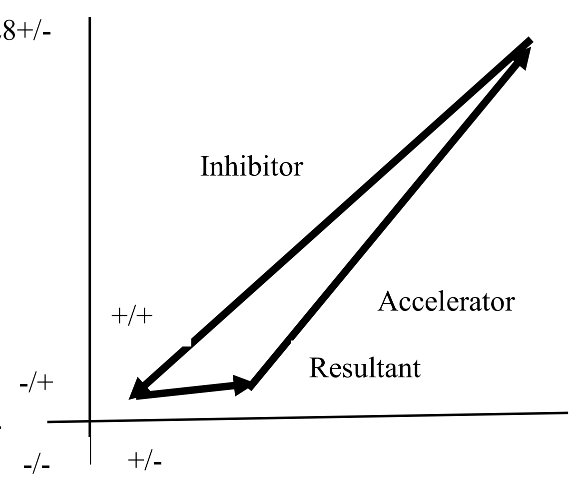


Fig. 5.26 Rate of Growth Vectorial Components (Pre-IR)

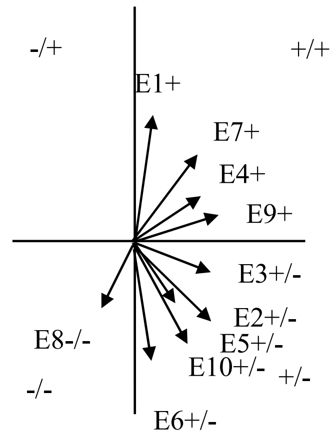


Fig. 5.27 EoI of Inhibitor Vector (I-IR)

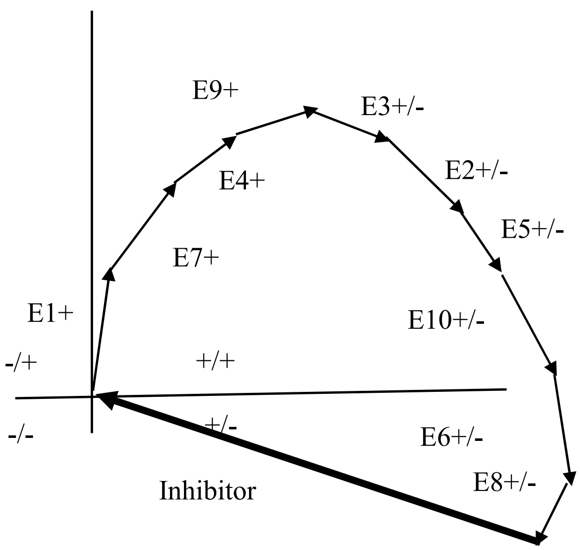


Fig. 5.28 Resultant Inhibitor Vector (I-IR)

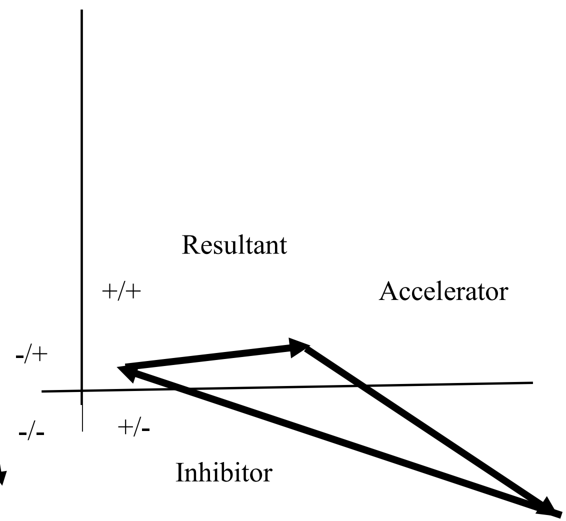


Fig. 5.29 Rate of Growth Vectorial Components (I-IR)

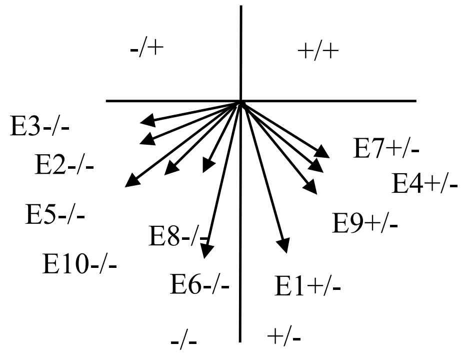


Fig. 5.30 EoI of Inhibitor Vector (II-IR)

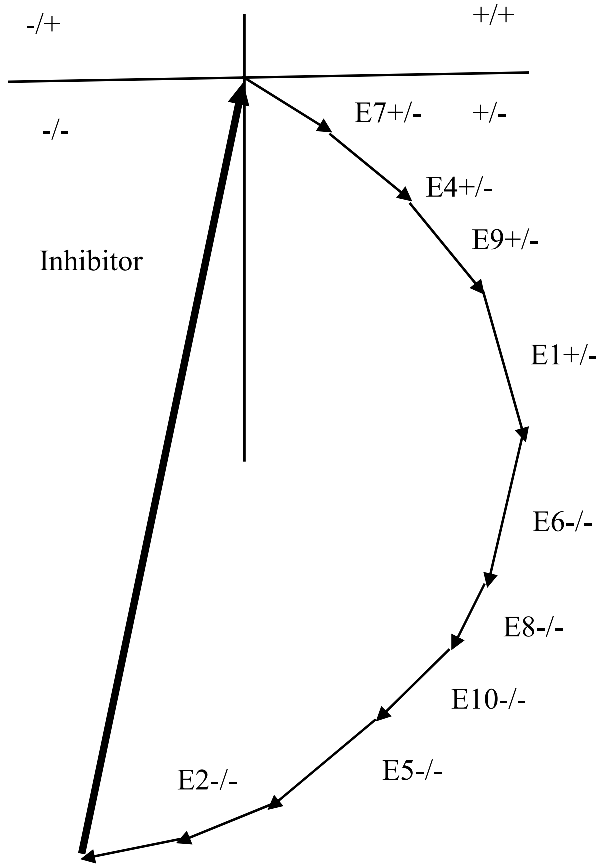


Fig. 5.31 Resultant Inhibitor Vector (II-IR)

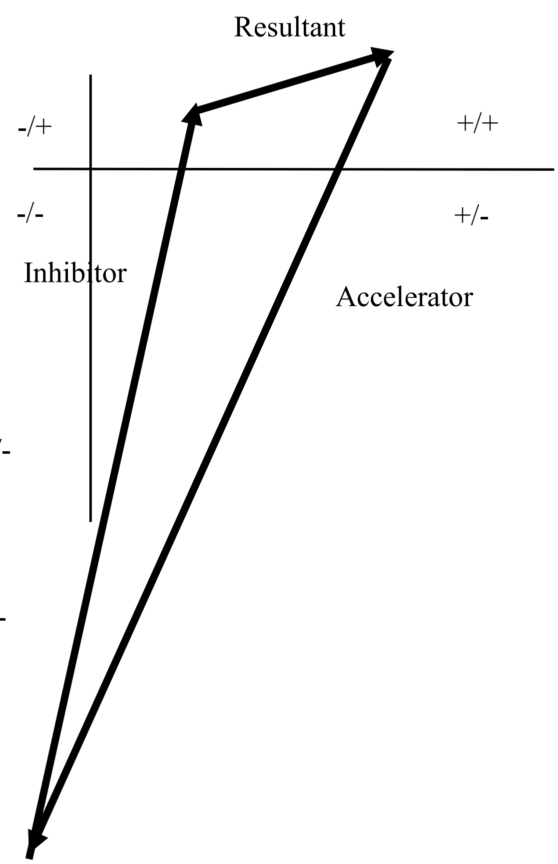


Fig. 5.32 Rate of Growth Vectorial Components II-IR

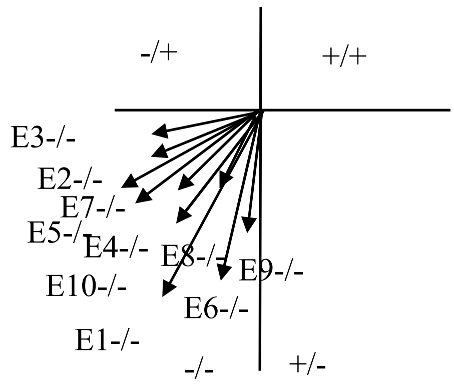


Fig. 5.33 EoI of Inhibitor Vector (III-IR)

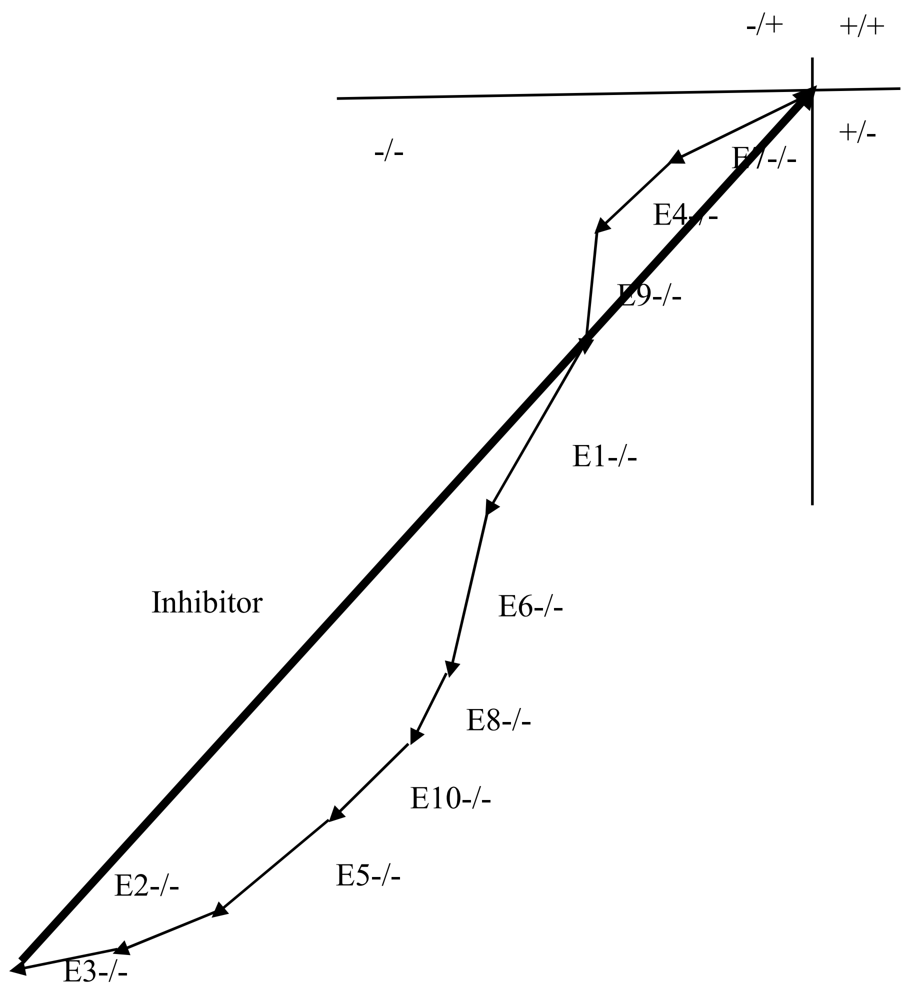


Fig. 5.34 Resultant Inhibitor Vector (III-IR)

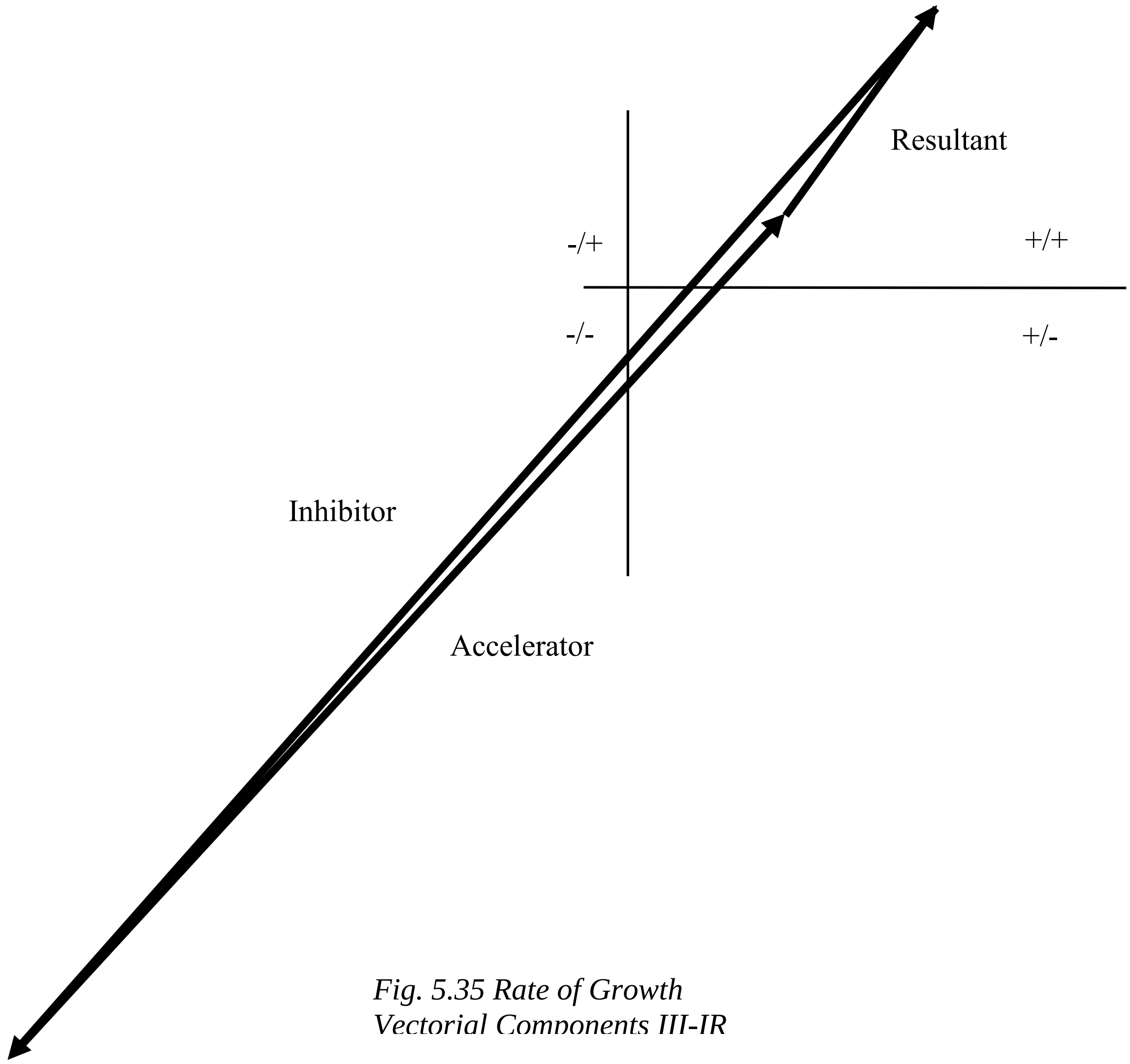


Fig. 5.35 Rate of Growth Vectorial Components III-IR

Principle 1 states that there are two types of sustainability: Natural and artificial. Regarding emissions natural sustainability is the capacity of earth to absorb emissions. Artificial sustainability is the capacity of elements of influence to tame the emissions exponentialoid to the level that natural sustainability can accommodate.

Principle 2 states that sustainability is a resultant vectorial force that acts upon an exponentialoid rate of growth. In this case, sustainability of emissions will be reached per Principle I.

Principle 3 states that an exponentialoid rate of growth is not a deterministic force, which is a simple exponential, but is constantly affected by the elements of influence vectorially.

Principle 4 states that these elements of influence are multiple and complex vectorial forces whose resultants are vectorial inhibitors (growth modifiers) and accelerators (potential growth). In the case of emissions, vectorial inhibitors overcome and surpass natural sustainability thus actualizing the accelerators (the potential for growth) of emissions. Another way of looking at this, the vectorial inhibitor has a resultant that is mirror opposite of the one shown in the Figures.

Principle 5 states that the exponentialoid strives towards an exponential in Cartesian terminology (in other words is similar) but more complex since the elements that influence its growth are multiple and complex.

Corollary to Principle 5 states that the same forces (elements of influence) that create an exponentialoid growth have the potential to tame it. Chapter 6 will present highly speculative and theoretical scenario where these forces tame an exponentialoid of emissions.

Relevance issue 1 expresses our hope that the heuristic and speculative nature of this presentation will transcend its instrumental value and acquire explanatory value after further work is done regarding a precise method for determining the direction and magnitude of each element of influence vector regarding emissions. In other words, the sense of this element can be discerned through historical research and analysis; however resolution of the direction and magnitude of these vectors are needed to complete vectorial analysis.

Relevance issue 2 states that the explanatory value is through universals which are highly symmetrical and perspicuous schema. In other words, this methodology, once perfected, should have multiple applications in the approach to complex, messy problems.

Relevance issue 3 states that the vectorial forces of the elements of influence are the cause (provided a necessary and sufficient set) upon the item in question, which in this case is emissions generation.

Relevance issue 4 states that artificial sustainability's elements of influence target the rate of growth of an emissions exponentialoid.

5.4.4 The case of building construction/high-rise, air conditioning and elevator/material consumption

Buildings are related on the input side of our argument with material consumption and on the output with emissions generation. The current case relates the elements of growth in the industry with the material consumption exponentialoid. In previous chapters we have presented the hypothetical case of increases in consumption of iron, copper, aluminum and lead. The growth curve of this consumption is exponentialoid. The elements that influence this consumption eventually will be the same elements that tame the growth in consumption.

Assumption One requires that an exponentialoid is unsustainable. Whether it is 100, 1,000 or 10,000 years, the fact is that openness towards infinity is unsustainable. The argument that other materials, energy sources, processes and technologies will be found is valid when considering the exponentialoid increase in science and technology. The historical precedent of the Industrial Revolution also indicates that when one revolution appears to wane, something else comes to the fore, independently, according to García Bacca (1989), which continues the advance of the General Economy. However, as stipulated, logic indicates that resources, per se, are limited.

Assumption Two requires that the exponentialoid rate of growth is affected by multiple, complex, independent forces. The forces affecting resource consumption originate in the elements of influence.

Rule One states that: there are elements that constitute a necessary and sufficient set of accelerators of rate of growth called 'potential growth.'

Rule Two states that: there are elements that constitute a necessary and sufficient set of inhibitors called 'growth modifiers'

Rule Three states that: the vector rate of growth (acting on population) is the resultant vector from 'potential growth' – accelerator, and 'growth modifier' – inhibitor vectors

Principle 1 states that there are two types of sustainability: Natural sustainability and artificial sustainability defined by the boundaries of natural and artificial manipulation.

Principle 2 states that sustainability is a resultant vectorial force that acts upon an (otherwise) exponentialoid rate of growth.

Principle 3 states that: the exponentialoid rate of growth is not a deterministic force but is constantly affected (modified) by the elements of influence.

Principle 4 states that: Elements of influence are multiple and complex vectorial forces whose resultants are vectorial inhibitors and accelerators.

Principle 5 states that: 'Exponentialoid' is used to express a growth curve that has a 'striving' towards the exponential in Cartesian terminology but differs in that it has multiple and complex sources.

Corollary to Principle 5 states that the same forces (elements of influence) that create an exponentialoid growth have the potential to tame it.

Relevance issue 1: Hopes that a vectorial interpretation of the multiple and complex forces at work that up to now can be discerned through soft-systems methodology, will manage to transcend its instrumental status and acquire, through both soft and hard system methodologies an explanatory value.

Relevance issue 2: Acknowledges that in order to reach explanatory value, a 'universal' presentation needs to be made.

Relevance issue 3: The forces 'are the cause, whatever it may be, which impress or tends to impress upon the body to which it is supposed to be applied.'

Relevance issue 4: States that 'artificial sustainability's elements of influence target the rate of growth of an exponentialoid.

5.5 CONCLUSIONS

We have stated that this is not a theory, but a set of heuristic principles at this point in time with need of further studies. The analogue story presented in this section is that complex forces can be viewed as a set of vectors in need of further definition and future quantification. There are independent as well as dependent forces at work. The independent forces will require deep data analysis which is beyond the scope of this dissertation and hopefully a work that others, like Chichilnisky and colleagues, will pick up.

The dependent vectorial forces are in the "changing terrain" category (Hawkins 1998) indicating that the vectors change over time, not only because the terrain changes (the state of the system) but forces that are not mutually independent have complicated mutual dependencies as observed in meta-system interaction. Knowing the mechanisms and applying quantitative techniques is a prime target for future studies.

CHAPTER 6

CONTRIBUTIONS AND FUTURE WORK

In this chapter 6, we are going to address the contributions and future work that stem from this dissertation.

6.1 INTRODUCTION

The dissertation identified in chapter 1 who says there is a problem, discussed the method of analysis based on soft systems thinking on its way to become hard systems in the future; established the dissertation objective to study the mechanisms and forces of an exponentialoid growth across several areas (population, affluence, consumption and emissions); and identified the stakeholders' concern. We also presented the criteria for choosing the high-rise, the air conditioning and the elevator as cases of for this analysis.

Chapter 2 elaborated on the problem of exponentialoid population, affluence, consumption and emissions and provided a foundation for linking these exponentialoids with building construction. The concept of needs and wants was elaborated since literature proclaims that we must change from a 'want' to a 'need' in General Economy that affects building construction, as well as all other aspects of life as we know it (the Jimmy Carter approach).

Chapter 3 dealt with the state of the art research on the systemic nature of the industry and its complexity; clarified the notion of building construction as a meta-industry in relation to manufacturing; introduced a method for analyzing the elements that historically have influenced change in population growth as a model for identifying the elements that have influenced industrial and building construction change. We observed that if building construction can be characterizised as being like manufacturing, the worldview that governs manufacturing would suffice to understand its mechanisms and complexity. However, our position is that building construction is not like manufacturing and thus is better captured by the schema of meta-system, meta-industry, industry of industries with other governing characteristics and thus a validation for the themes of this dissertation. The criteria for drawing the boundaries that capture the necessary and sufficient element of influence were identified.

Chapter 4 analyzed the complexity of the building construction industry, elements that historically have influence change in building construction as found in the annals of the industrial revolution and specifically building construction through the surrogates of high-rise, air conditioning and the elevator. Chapter 4 also provides a philosophical theoretical framework for identifying a building construction worldview, the philosophy that informs it.

Chapter 5 proposes that the same elements that have influenced the creation of an exponentialoid are the elements that should have the potential for taming it. Using analogue thinking techniques we weaved the exponentialoid with the elements that influence change with the caveat that future work in a vectorial calculus type of language is needed to flesh out a quantifiable architecture once the protocols are established along with further studies in the area of threats and opportunities. We presented a highly speculative scenario regarding the derivation of a vector analogue using the aspects of origin and sense taken from historical thinking perspective in this analogue presentation. The aspect of magnitude remains to be studied to complete the evolution from a soft system to a hard system thinking advanced by this framework.

6.2 CONTRIBUTIONS TO NEW KNOWLEDGE

The contributions to new knowledge in this dissertation are:

- A better understanding of the complex forces of change in construction
- An understanding of the needs and wants concept that underlies exponential

growth in construction
- A better understanding of natural sustainability and artificial sustainability regarding the population and demographic (affluence) drivers as they affect construction
- A philosophical understanding of artificial sustainability as the force that tames an exponentialoid growth
- The introduction of an analogue that could inform the future inquiries and postulations of quantifications and offering of explanations of an exponentialoid
- Identification of future work in the areas of direction and magnitude of the vectors

Sustainability, as the force that tames an exponentialoid, is more complex and a property of a process rather than the current understanding of sustainability as the property of an object. In the context of this dissertation, other disciplines with their processes must conspire with their forces; otherwise the results will fail to tame an exponentialoid in the short and long term horizons. The logic behind this theory is that complex forces, historically, have contributed to the emergence of the exponentialoid, therefore these same forces must now re-align themselves (change direction and magnitude as in vectorial thinking) to significantly contribute in achieving the intended results.

The other disciplines mentioned include the policy maker, building construction executive and critical thinkers targeted at the beginning of this dissertation.

6.2.1 Policy maker

The dissertations highlight the background of the issues and problems and in a pre-paradigmatic sense have established a worldview, a framework or hopefully at some level a vantage point for looking at the problem. Policy makers need to fully understand the implications of the current IV Industrial Revolution, the issues behind population (growth as well as diminution) and affluence growth as they relate to resource consumption and emissions generation. Policy makers should promote the continuation of a comprehensive study on the following:

- The forces that are driving current and future needs and wants
    - An accurate assessment of the population growth characteristics
        - (for example, the latest indicators are for a regression towards promoting growth in countries suffering from negative population growth such as: Cyprus, the Czech Republic, Greece, Hungary, Slovenia and Portugal; Russia, Japan, and others not far off such as France, Britain, Germany FT 10/13/06)
        - China loosening the one child policy!
    - An accurate assessment of consumption patterns and trends
- A continued study of the forces that create an exponentialoid
    - Creating a global task force for a continuation of this dissertation by testing
        - The assumptions
        - The arguments
- Research and Development for the study, identification and creation of an appropriate language (symbols and meanings) that captures the forces of complexity
        - The identification of the disciplines needed
        - A protocol for selecting the scientist
        - Securing sufficient grant money for the study

This work should appeal to the policy makers of all countries and with the tools of the IV IR a true global team could be identified for the task. For example, China's recent accomplishments are extraordinary indeed and even more is the potential for additional accomplishments that could take it beyond known scales of production, consumption and emissions. China and India are excellent possible case studies for research within their own societies by PhD students that understand these forces, some as they originate, change sense and gain magnitude. These independent study cases could be the backbone of a process to verify the template, proto-theories and philosophies of this dissertation. Policy makers in China and India have a vested interest in preserving the momentum of growth of their respective economies while at the same time taming an unsustainable exponentialoid.

Identifying those that should be involved in the research and a mechanism for funding is critical. Extensive future work is contemplated for those that find the presented insights moving, compelling, or worthy of committing time and effort to identify theories and hypotheses to sift through a rigorous scientific process and bear the criticism that paradigm changes entail.

6.2.2 Building Construction executive

The building construction executive is well served to see sustainability as an issue not of a product but and a property of the process of the industry. Only with this worldview will the necessary forces be marshaled to make a dent on the problems. The worldview of a building construction executive needs to include the predicament that resource consumption and emissions generations have on business and society. This predicament will inform decision making in short and long term horizons and should marshal the required research and development strategies of the company to anticipate and be proactive. Such a position should differentiate the company from the laggards and the business as usual.

Although the early investment in strategizing and positioning will probably be time sensitive, the exponentialoid in all cases indicate a time compression that is taking everyone by surprise: from the ice melting, sea rising, energy consumption, material depletion and environmental degradation among others.

The situation is no longer ‘good public relations’ a ‘marketing ploy’ or ‘good practice’ but one that most likely will end up at the level of national security if not global security. Instability of the global, regional or national economies will affect the way we relate at all levels. Such cases bring another dimension to the word crisis and catastrophes that is beyond the scope of this dissertation but within its plausible boundaries. Crisis and catastrophe may be what is required to marshal all the necessary forces to confront the current predicament, as it must have done during the bubonic plague that resulted in all the changes in the spheres of life that created the propitious conditions for the industrial revolution and population growth that many generations have experienced. Just like at that time the response by the leadership during 400 years of crisis is anonymous, except for the major inventors and entrepreneurs, a cadre of leadership at all levels of the amorphous conglomeration called the construction industry may be required, along with the leadership of all other industries, acting independently or in concert with or without the government support and cheering, a la France.

Current initiatives do not measure and are not scalable, so the field is wide open for inventions that are not in the radar screen of anyone. This radical, first time technology, will provide the clear differentiation needed for a breakthrough in the process and thus in the way society tackles unsustainable exponentialoids.

6.2.3 Critical Planners

Critical planners' worldview needs to account with the possibility that a significant portion of current world assets may become un-useable in the near future and the mode of replacement of those assets may contribute to an increase of other major problems or become the catalysis for the direction of a long lasting solution. To avert this predicament, further R&D by the best minds in the theoretical and practical fields needs to be done to identify the language that captures the forces that influence exponentialoids and build the models that will serve to support decisions making.

6.3 OBSERVATIONS

The varied world-side initiatives to sustainability are indicative that the topic is receiving international attention. However there is no published research acknowledging the exponentialoid nature of the challenges as presented in this dissertation. Apparently all these activities towards sustainability are being carried under the 'precautionary approach' - it is better to do something rather than to do nothing. The focus of this pre-paradigmatic dissertation is to identify, through philosophical tools, the nature of the problems and the characteristics of the exponentialoid. The problem is complex and requires approaches that integrates complexity rather than reduce it to manipulative mathematical constructs. We have taken the position that a better worldview of the nature of the industry in its complexity is needed as a basis for future multi-discipline work.

The original goals of this dissertation have been achieved and the questions raised have been answered. The stated deliverables in this pre-paradigmatic work were: (1) A better description of the challenges to the building construction industry in this Century (the exponentialoids and how they relate to building construction); (2) A theoretical framework/model of how these challenges and the industry interact (identification of the elements that historically have influenced change); (3) A study of the industry's systemic nature (the complexity of the industry); (4) An analogue graph or model of the interaction between the historical mechanisms for change and the exponentialoid).

> (1) A better description of the challenges to the building construction industry in this Century (the exponentialoids and how they relate to building construction):
> Analysis of the forces (population number and affluence - increase in standard of living) indicates production/material consumption and the emissions generation with an exponentialoid growth trend in regards to building construction (for the purposes of this dissertation). A Defining characteristic of an exponentialoid is openness to the

infinite. Logic indicates that indefinite, long horizon consumption along this trend is unsustainable.

General Economy theoreticians prescribe that as resources become scarce a threshold is crossed where price increases, demand decreases and other resources are developed to take its place, which is the general trend we are currently experiencing in fossil fuels. However building construction materials have not crossed that threshold although we have experienced selected doubling of prices in an otherwise flat inflationary history.

The rate of acceleration of an exponentialoid indicates that within this century (short term horizon) we may be experiencing selected depletion of readily available resources. This in turn may place an increase in the demand on other resources that are acceptable substitutes and thereby accelerating their own depletion.
In addition, we may be at the threshold of increasing number and magnitude of catastrophes due to the exponentialoid growth of emissions generation and possibly a vicious self perpetuating natural cycle that aggravates artificial contributors. These catastrophes as they appear may increasingly place a demand on building construction to rebuild or replace existing capital asset stock further aggravating the question: Is building construction approaching the threshold of becoming unsustainable?

(2) A theoretical framework/model of how these challenges and the industry interact (identification of the elements that historically have influenced change):
On the other side of the equation is building construction capacity to change that can only be gleamed from historical records. Specifically, although not elaborated in this dissertation is the Bubonic or Black Plague that decimated population numbers, a catastrophic event lasting several hundred years but ultimately leading to changes in hygiene, potable water resources, collection and treatment of waste, medicine, industry and all the sciences at the expense of governmental systems such as Feudalism and religion. The case in point is that a catastrophe motivated broad changes that eventually improved living conditions and created the population number and affluence problem we now face.

(3) A study of the industry's systemic nature (the complexity of the industry)
If technological creates a problem, only more technology can solve it. The new problems need to be framed both from the side of the exponentialoid and from the side of the capacity to change that both created and solves the problem (with the caveat that it may also create a bigger and unsuspected problem, if history is any indication of trends).

In order to address the building construction capacity to change we first have to get a worldview of the so called building construction industry or sector. When we do a state of the art analysis of what researchers are saying we find that an industrial model does not fit and being at a loss for a better definition at this time we looked at other models such as a meta-industry. The capacity for change resides with the elements that have influenced change in the past, again, at a pre-paradigmatic, worldview level that begs translation and further definition.

(4) An analogue graph or model of the interaction between the historical mechanisms for change and the exponentialoid)
Representative graphs were presented on the anticipated and possible action of a vectorial construct of the interaction between the historical identified mechanisms for change and an exponentialoid in the case of population growth. Although the theory remains to be proven (and thus a theory with in this case a direction on how it could play out), the logic at a macro level has been derived with a novel methodology from historical analysis.

The question "Is building construction approaching the threshold of becoming unsustainable?" based on logic, with the current trends, on a short term horizon, if the concatenated events projected from emissions generation develop, is a philosophical YES. This answer, at the current curving section of an exponential "J" begs a closer look at global, national and regional growth patterns in building construction and specifically trends in material consumption, emissions generation on both short and the implications for a long term horizon.

With the presented framework we now approach a highly theoretical scenario that showcases how the sense of the elements of influence can evolve through beneficial artificial sustainability in taming the exponentialoid of emissions.

6.3.1 Theoretical scenario of artificial sustainability taming the emissions exponentialoid.

The case1 theoretical example in the evolution of the sense of the elements of influence finds some elements moving towards a negative/positive and others towards a positive/positive sense. Case 2 theoretical example continues the movement of the sense towards a positive/positive (see *Fig. 6.1)*

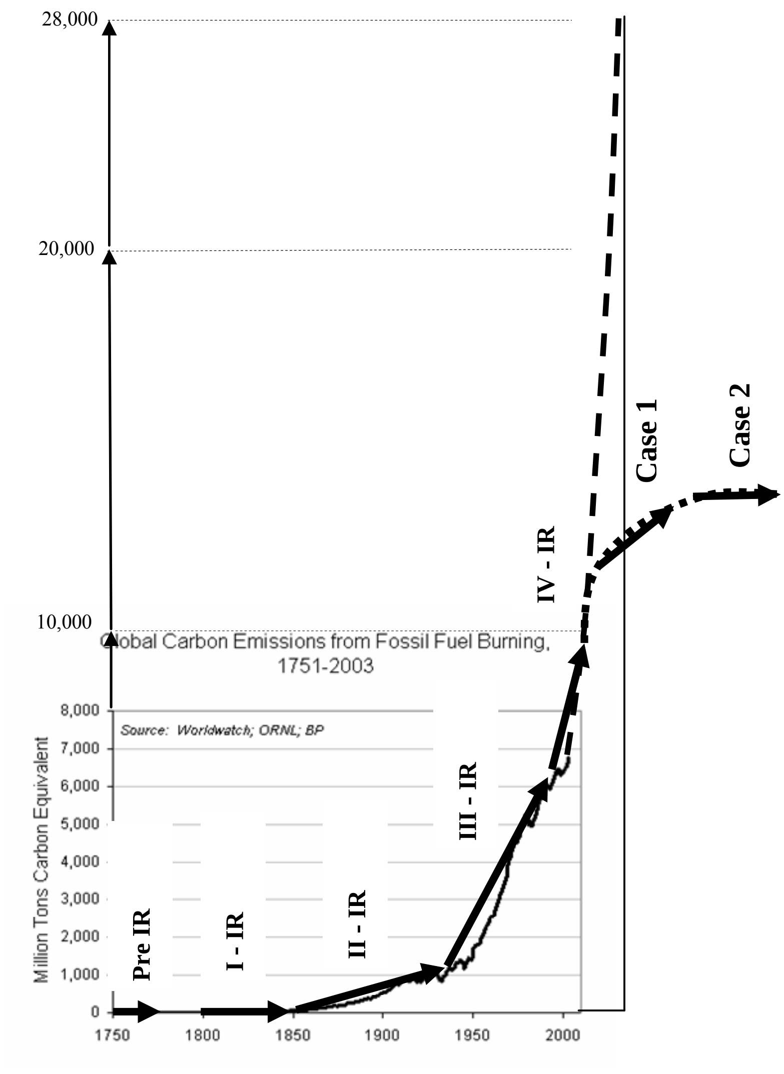


Fig. 6.1 Taming Global Carbon Emissions

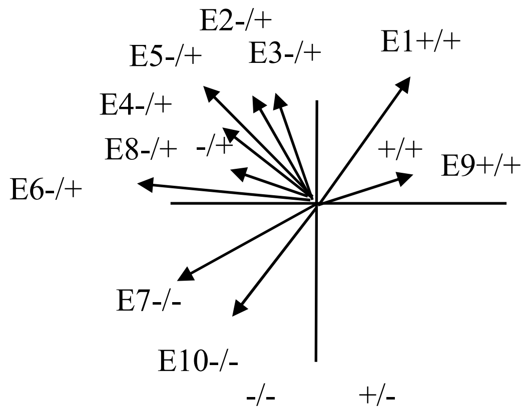


Fig. 6.2 EoI of Inhibitor Vector (Case 1)

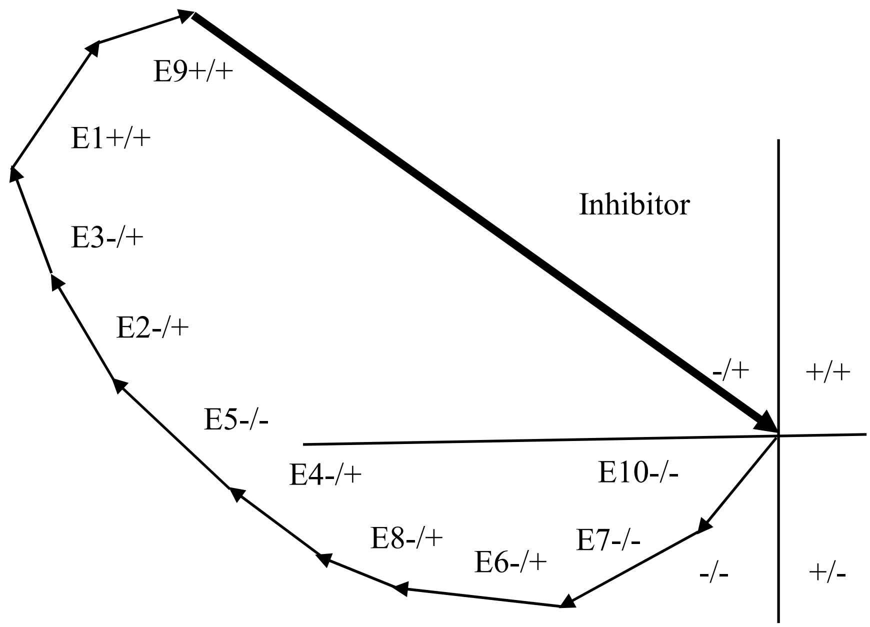


Fig. 6.3 Resultant Inhibitor Vector (Case 1)

The change of 'sense' of the elements of influence, in this theoretical case, affects the rate of change of the vectors that cause the exponentialoid. How does in effect can the elements of influence change 'sense'? Take one of the EoI, technology:

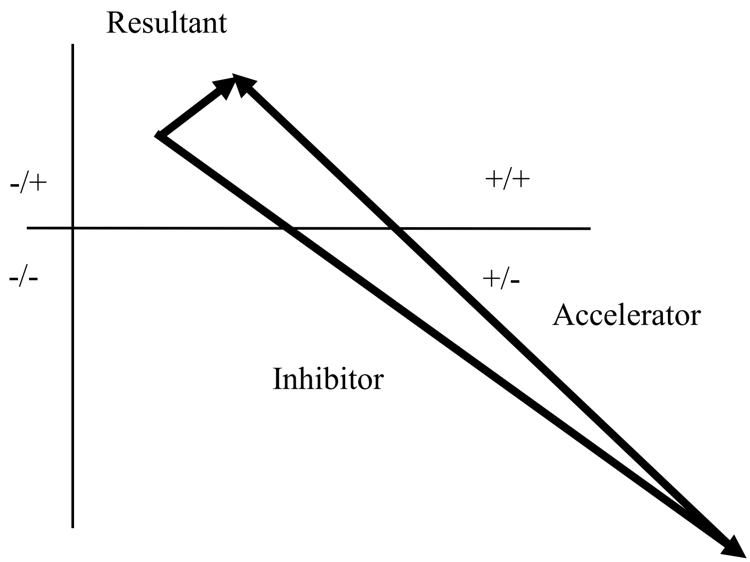


Fig. 6.4 Rate of Growth Vectorial Components (Case 1)

- Technology in the Pre-Industrial Revolution was not an element of influence (NA).
- Technology in the I-IR (positive/positive) became a player through mass production of artifacts but without a significant impact on emissions generations.
- Technology in the II-IR (positive/negative) substantially increased emissions generations by virtue of the production numbers and types.
- Technology in the III-IR (negative/negative) continued to increase at an exponentialoid rate both the production and types of artifacts for consumption.

- Technology in Case 1 starts to develop clean techniques for production and fuel efficiencies.
- Technology in Case 2 (see *Figs. 6.5, 6.6 made 6.7*) is developed to the extent that de-materialization becomes a reality (possibly through nano-technologies) and sources of energy are found that are non pollutant for transportation, power generation, construction and others.

The power source, for example, is beyond atomic energy, are infinite in resource, transportable and storable. The transportation of this energy is done without power loss and thus motor efficiencies reach exponential levels of efficiencies. Previous technologies continue to be employed but are replaced when obsolete or are no longer economically feasible.

This however is the theoretical possibility of only one of the vectors. That is, even though it has a possibility for being a major contributor, to taming the exponentialoid, unless all other elements of influence somehow contribute with direction, sense and magnitude, because of the nature of an exponentialoid, it may not be tamed. Consider the current observation regarding population: Even a one percent increase in population, it is currently estimated to adversely affect the possibility of reaching a sustainable state (see *Fig. 6.7*).

This examples showcase that the magnitude of the vectorial forces is much greater when taming an exponentialoid as time goes on since the accelerator force is correspondingly much greater. Exponentialoid growth has four alternatives: 1. Continue the growth indefinitely, even at a moderate rate (an unsustainable position); 2. Stabilize the growth; 3. Reduce the growth; 4. In the case of material consumption, find a substitute that can be scalable, can sustain exponential growth indefinitely without detrimental effects and thus allow the original material achieve stabilization or reduction.

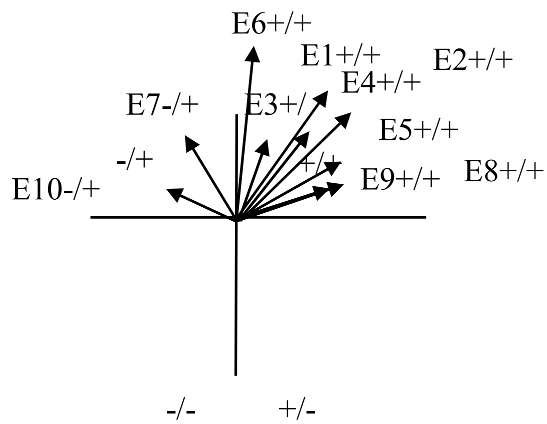


Fig. 6.5 EoI of Inhibitor Vector (Case 2)

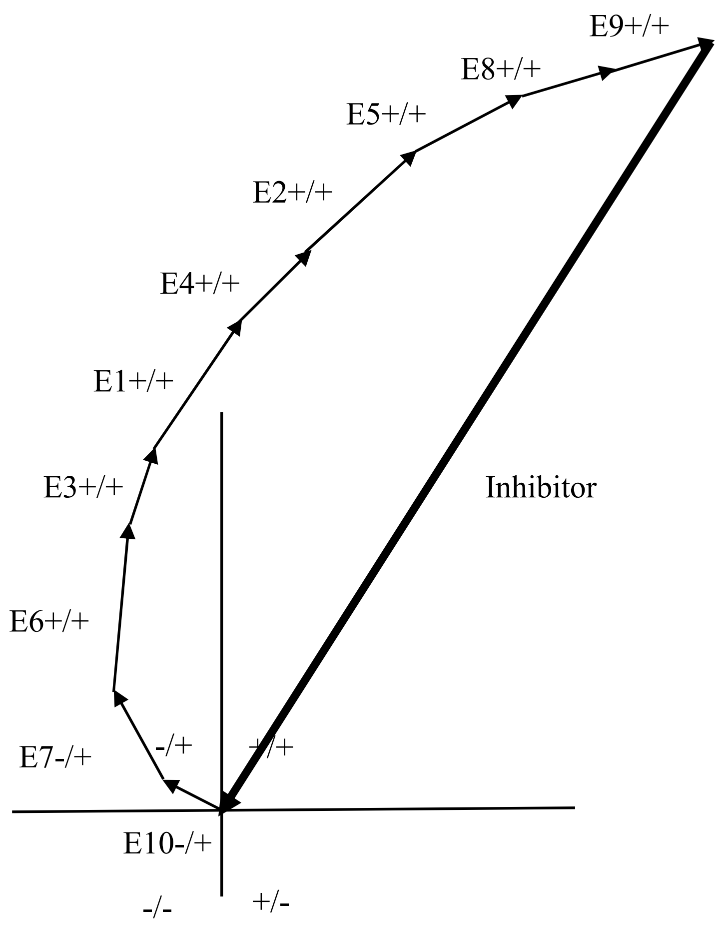


Fig. 6.6 Resultant Inhibitor Vector (Case 2)

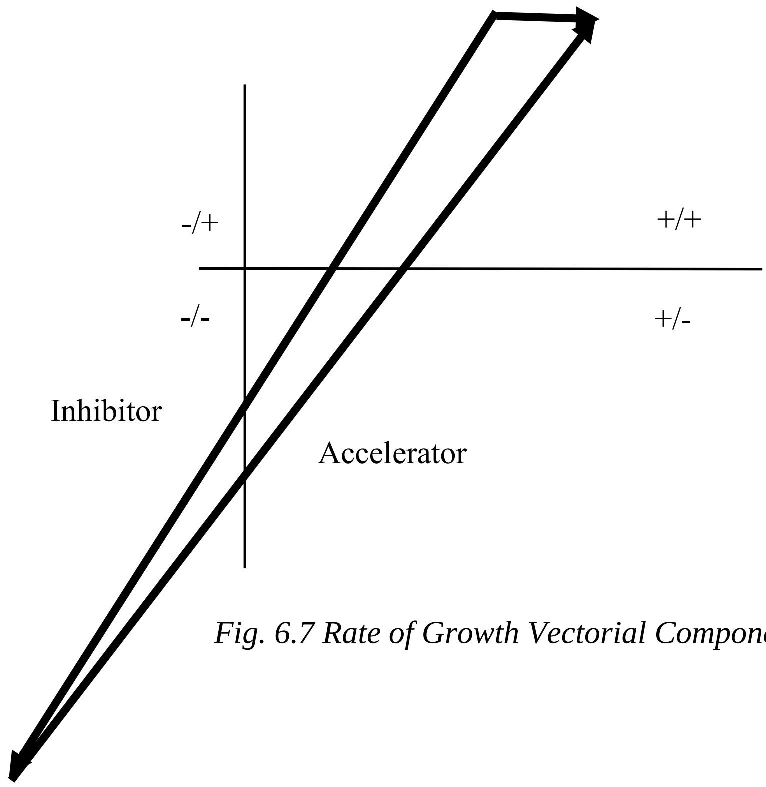


Fig. 6.7 Rate of Growth Vectorial Components (Case 2)

6.4 IDENTIFICATION OF FUTURE WORK

The identified elements of influence in the different scenarios, population, industry, and building construction change 'sense' in a time-line analysis. For example, regarding the industry, the EoI 'sense' changes in time caused by the different forces acting on the several industrial revolutions. The observed changes in emissions are also time related thus linked to the different phases of the industrial revolution. Further studies are needed to establish a closer link between the EoI with each exponentialoid in question.

This future work regarding each EoI must also be linked between the different disciplines using a methodology that cuts across disciplines and is based on an agreed protocol so that it fits within the overall systems architecture. The results of this future work must be in terms of direction and magnitude to fit within the vectorial analysis framework proposed in this dissertation. *Fig. 6.8* is a characterization of the proposed future work, given that the present work has identified the world view and the affected system. Guidelines of the enabler and the

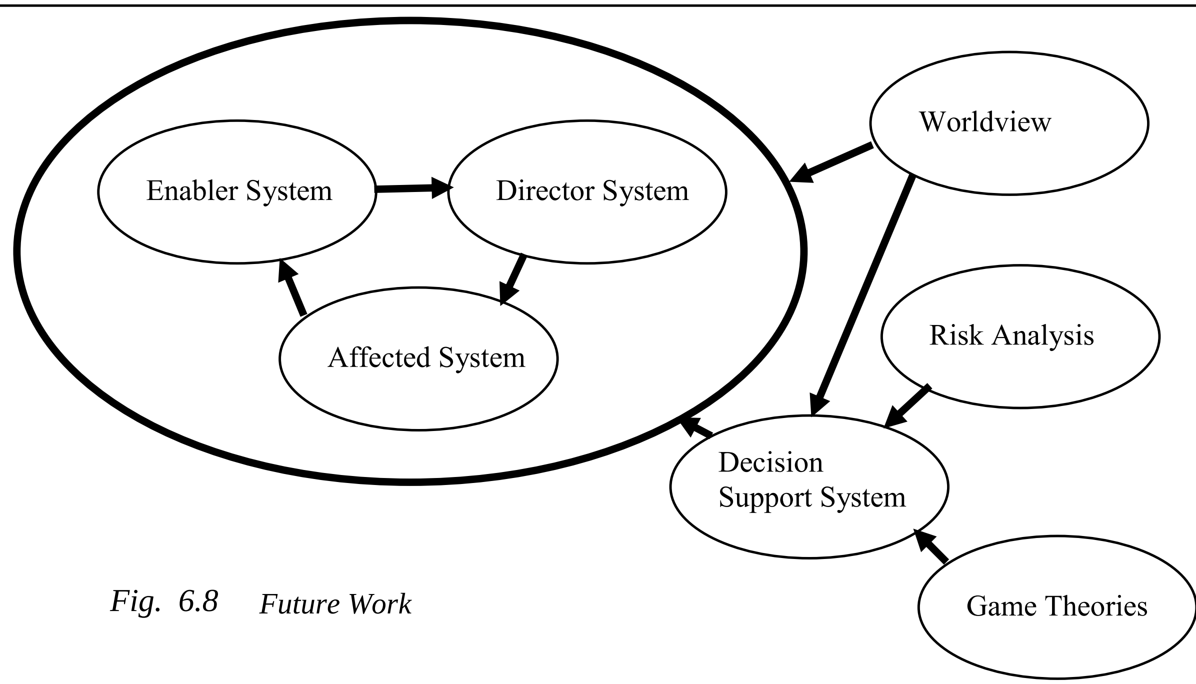


Fig. 6.8 Future Work

director system have also been identified through this work, although additional research needs to be done in the above mentioned areas of direction and magnitude that specifically link the systems in a vectorial framework. Furthermore Game Theories and Decision Support Systems could be identified in order to investigate theoretical scenarios.

Vector calculus, like meta-systems, has the potential to lead us into a language of derivatives and integration of multi-dimensional forces beyond our grid and systemic thinking. They represent a point of reference to start looking for a language that captures qualitative, quantitative original concepts that capture the reality we suspect exists.

The current thinking is to form a team of interested researchers that want to embrace this quest, a quest for a language, and find who else we think needs to be on a limited seat bus, at this time. Once we have a full bus, then we need to determine where we want to take the bus, knowing that there will be a dynamic ride with variable riders.

In short, and personally, I think and conceptualize graphically. My natural language is graphic based. My advisors will testify that long before words could describe them, nonsensical graphics began talking to me. I certainly hope that we will have that talent in the bus if we determine that one of the characteristics of vectorial language is graphics.

6.4.1 Identification of the instruments needed for gauging the magnitude of the EoI.

The envisioned future work will start by applying for research funding based on the findings and directions of this dissertation. Sufficient funding should be requested for a coordinated research by various interested experts in each one of the disciplines or areas identified by the EoI. Among other tasks, the identified group should have in their agenda to establish a protocol for the investigation, and a schematic of the system's architecture, and the identification of perceived threats.

CIB could become a source of experts from an international task force created for the research. A colloquium could take place within two or three years to disseminate the findings as well as to raise interest in the work and identify research work from others that could have a bearing on the subject. A common denominator of the task force will be an understanding and familiarity with calculus vector analysis and theory since this topic is foundational to the approach.

6.4.2 Vision for a Web-based open Systems Architecture

The research group could use web-based open systems architecture as the platform, with secured access, for sharing the progress and findings with other members of the task force and identified interested scholars in the fields of the research.

The task force will be required to publish journal papers that are peer-reviewed and encouraged to present the work in national and international forums.

6.4.3 Proof of the concept study

The next stage of research could be a proof-of-concept study directed at identifying a surrogate exponentialoid. For example, a surrogate exponential, such as population growth and apply a more in depth analysis to the elements of influence. A priority could be an independent validation of the set of 'elements of influence' and a more in-depth study of origin, direction - its taxonomy for change, and magnitude. The element of specific origin and study how the insertion of that force on an otherwise existing dynamics (albeit one of life, growth and death) affects the exponential in such a way that an exponentialoid results can be observed.

Once we understand and know how to marry a qualitative taxonomy of change, quantitative magnitudes and points of origins, we may be at the threshold of discovering a new language (similar and different from each of the components) that better expresses the notions found. Our challenge will be not to try to force existing languages into its form. This would be a bias towards safeguarding what we are familiar, the old paradigm.

The ultimate issue is then philosophical and not mathematical: What is the language that will better symbolize and thus capture the meaning of what we are trying to uncover. Which follows, what is what we think we are looking at? Which is dependent on what is our point of view on a worldview?

6.4.4 Reverse Road Mapping

Science and technology road mapping has become popular in recent years. Causal Loop Analysis and road mapping used in parallel, with an application of the historical analysis method has some possibilities for future work. For example Fig. 4.8, represents a kind of "reverse road mapping" where additional methods may be used to reinforce the findings.

6.5 CONCLUSIONS

The following points need to be mentioned regarding this dissertation:

- There is no comprehensive worldview that emerges from this work, but a partial building construction worldview
- Systems simulation offers little hope or help in analyzing complex problem situations
- The identification of major forces regarding the exponentialoid and the elements of influence seems to be tractable and could lead to a new paradigm in studying sustainability
- However, we are still in the pre-paradigmatic stage
- One useful way to formulate a pre-paradigm is attempted in this dissertation
- The work is based on a force analogue and qualitative assessments grounded in the inquiry of the previous chapters

Time is of the essence for a better approach that captures the elements of complexity, and the motives underlying this dissertation, in agreement with Descartes, remain excellent.

APPENDIX A

GLOBAL WARMING AND DEMOGRAPHIC CHANGE

Climate change, as currently predicted, increases the magnitude and quantity of catastrophic events. Catastrophic events, in built up areas with dense population concentration, translate into greater human suffering and for the purpose of this study, an additional demand on resources to repair or re-build. This additional demand due to catastrophes closes the catch 22 circle of resources, waste, pollution and climate change. This scenario is being played in the Gulf of Mexico region where a 'category 5' hurricane, with 145 miles per hour wind struck the New Orleans area in August 2005, creating, up to now, what is estimated to be the most expensive disaster in the US history. The Tropical Hurricane season of 2005 has been the most active for hurricanes (17) and tropical storms in the Atlantic since 1995 (19) due to favourable wind conditions and sea surface temperatures (above 26° C).

Global warming affects not only the creation of hurricanes, cyclones and typhoons but a host of other environmental changes such as, melting of the ice poles, rising of the seas, increased precipitation, increased snow-fall and ice storms, increased adverse weather from hotter days to colder days reaching 1000 year records and surpassing them, draught and floods that also surpass the 100, 500 and 1000 year records from what can be perceived in the annals of human history, embedded in the tree ring records and throughout geological search. Taking hurricanes and typhoons as examples of the ongoing arguments:

Twenty typhoons are predicted to hit Asia in the 2006 season (FT 10/13/06). As companies increase to globalize, they are increasing their exposure to risk since most of the Asian expansion occurs in the Pearl River Delta of China. This area is more prone than New

Orleans to flooding. "Eighty percent of foreign direct investment in China is concentrated in seven coastal provinces and towns." The world is becoming a riskier place and more weather exposed. Supply chains were the top concern for 25% of North American companies and 19% of companies elsewhere in the world.

The debate over whether global warming affects hurricane activity continues. The Journal of Science notes that an increase in the strength of hurricanes over the last 35 years parallels an increase in sea-surface temperatures. However, the countervailing view states that hurricanes are not 'linked' to global warming, but follow a cycle of activity in which decades of relative calm are followed by years of more intense storms. Like with the issue of economics, long term data offers a model of predictability that does not take into consideration possible and permanent changes that make the model dynamic and irreversible with new and unprecedented characteristics.

American Meteorological Society's Environmental Science presented on Oct. 25th in Washington D.C. the following Seminar: Hurricanes: Are They Changing and Are We Adequately Prepared for the Future? Moderated by Dr. Socci with Drs. Trenberth, Curry and Emanuel[136] Presenting: Is There Evidence That a Global Warming is Altering Hurricanes? – Setting the Context:

> *Are the bonanza Atlantic hurricane seasons of 2004 and 2005 becoming the norm? Is the record breaking number of typhoon hits in Japan in 2004 a wave of the future? Does the first known hurricane, Catarina, in the South Atlantic in March 2004 signal more? The climate is changing, and humans are partly responsible. Global mean temperatures continue to increase and are running 1°F or more above pre-1970s values. While 1998 remains the warmest year on record, 2002, 2003 and 2004 follow closely behind. These changes have*

[136] Dr. Kevin Trenberth, Head of the Climate Analysis Section, National Center for Atmospheric Research (NCAR), Boulder, CO; Dr. Judith Curry, Professor and Chair of the School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, GA; Dr. Kerry Emanuel, Professor of Atmospheric Science, Massachusetts Institute of Technology, Cambridge, MA.

been definitively linked to increases in greenhouse gases in the atmosphere, most notably carbon dioxide, which has increased 30% in the past Century and half of that increase has occurred since 1970. This increase is from human activities and especially the burning of fossil fuels. As part of this global warming, sea surface temperatures (SSTs) in the tropics have increased 0.9°F since the early 1970s, and this increase is unprecedented over at least the last 150 years and perhaps the last several thousand years. It is almost certainly a result of the additional greenhouse gases mankind has put into the atmosphere. Associated with this is an observed increase in atmospheric moisture (water vapor) on the order of 4%[137]. *This increases the energy available for storms and enhances the chances of heavy rains.*

Hurricanes occur only where SSTs are above about 80°F, but they also require favourable atmospheric circulation patterns to occur. There is a natural competition within the tropics for where these conditions are most favourable for hurricane formation; during El Niño it is the Pacific, but since 1995 the Atlantic has been favoured except in 1997 and 2002 (both El Niño years). Locally in the Atlantic, natural variability is large from year to year, and even from decade to decade, as the ocean currents alter SSTs and change the odds of hurricanes forming.

Observations clearly reveal increases in heavy rains in the United States and many other places around the world. Sea level has risen over an inch in the past decade, as the ocean waters warm and expand and glaciers melt. An estimate of the effect of global warming is for about 7.8% enhancement of heavy rainfall and associated latent heating in the storms since the 1970s. An unanswered question is how many of these hurricanes will make landfall and where. Nevertheless, the environmental changes related to human influences on climate are increasing the risk of major flooding associated with hurricanes.

New Data/Evidence for Increased Hurricane Intensity:

About 90 tropical cyclones develop around the world each year, and roughly, half become strong enough to classify as hurricanes (or typhoons in the western Pacific region). While this global number changes little from year-to-year, there can be large changes in the frequency of events in individual regions. For example, Atlantic hurricanes are subject to large year-to-year and decade-to-decade fluctuations, both in the number of storms and in their intensity and duration. The fluctuations have been related to natural climate oscillations that affect the whole North Atlantic region, and to the well-known El Niño phenomenon. For example, the 1940s and 50s were very active years in the Atlantic, wile the 70s and 80s were quiet. During this most recent quiet period,

[137] The relationships among changing atmospheric moisture, energy availability and how storms develop is a topic of considerable ongoing research.

there were large increases in coastal population and infrastructure in the U.S. These increases, coupled with the return of an increase in the frequency of hurricane activity beginning in 1995, have led to a very substantial increase in hurricane-related losses in the U.S.

Recent scientific research suggests that the duration and intensity of hurricanes worldwide has increased dramatically over the last 30-50 years. Analysis of global hurricane data from satellites (which is available since 1970) shows that the strongest hurricanes (categories 4+5) have almost doubled for the period 1970-2004, and this increase is seen in each of the ocean basins for which hurricanes occur. This increase in hurricane intensity is coincident with a global increase in tropical sea surface temperature, which is evident in each of the ocean basins. In fact, tropical ocean temperature has increased by about 1°F over the past 50 years, and this increase is unprecedented over at least the last 150 years and perhaps the last several thousand years. While sea surface temperature is not the only thing that determines hurricane intensity, there is strong empirical and theoretical evidence that on average an increase in sea surface temperature will increase the average intensity of hurricanes. What has been producing this warming? Solar and volcanic activity has actually been working during this period to produce a slight global cooling. As stated above, the decadal scale variability seen in the North Atlantic is regional and cannot explain the global increase in tropical sea surface temperatures. Particularly during the period since 1970, greenhouse warming is the best explanation that we have for this temperature increase.

What is the future likely to hold?

How will hurricanes change in the future? Our best estimate is that tropical sea surface temperature will continue to increase, driven largely by greenhouse warming. While climate models do a good job at simulating the past surface temperature record and arguably are producing reliable projections of future surface temperature changes, we do not have much confidence in projections of future hurricane characteristics. Climate models do not do a good job of simulating hurricanes because their resolution is too coarse and there are numerous uncertainties in modelling hurricane processes. These uncertainties include incomplete understanding of hurricane intensification and processes occurring in the hurricane eye wall and the nature of the interactions between the atmosphere and upper-ocean during the hurricane evolution. Based upon our current understanding relating hurricane intensity to tropical sea surface temperature, we would expect hurricane intensity to continue to increase at least in the short term as sea surface temperatures rise. However, our basic understanding of the global climate dynamics of hurricanes is not adequate to have much confidence in future projections. Nevertheless, research indicates that we are facing a serious risk in the coming decades of increasing hurricane intensity.

Moreover, increases in associated heavy rainfall events and risk of flooding are also real. Even as better hurricane forecasts have reduced losses and loss of life, increases in coastal population and wealth, coupled with the return of large hurricane activity beginning in 1995, has led to a very substantial increase in hurricane-related losses in the U.S. It is important to recognize that because of global warming, the past is no longer a good guide to the future, and planning of all sorts should build in the best estimates for changes in the range of risk especially in potential damage to infrastructure, flooding and water management, and in insurance. The failure of the levees near New Orleans is a case in point.

Demographic change

Demographic change continues to be the focus of our concern. Although UN studies in 1999, as well as the US Geological Survey predict ample supply of resources, China's exponential economic growth that translates into an aggressive infrastructure and structural growth in building construction (with no end in sight in its capacity to grow) was not apparent at that time. In 1999, only six years ago, the rapid movement of major population centers into higher standards of living was not envisioned to affect the market price of resources, the global capacity of basic materials, the stock pile of availability and capacity of processing and transporting the materials, etc.

In 2004 China brought 70,000 Mega watts (Mw) of new electrical capacity on line – an mount almost equivalent to Great Britain's entire existing power generation capacity, with similar increases in magnitude scheduled to be brought on line in 2006 and 2007. However, what is telling regarding this increase is that in 2005 the government has ordered the halting to construction of 'unauthorized' new plants with a total capacity of 17,000 Mw. Considering that the authorized increase consists of 80% power derived from coal, it is highly suspect that the "unauthorized" plants have the latest scrubbing technologies. Somewhere in the last three years, a change has taken place in the emissions of carbon that have created an increase from 6.8 Giga tons to 28.0 Giga tons with a new t_c of 1.

The remaining 20% of China's new electrical power comes from oil, gas and nuclear. Although not much has been published about the oil and gas, some facts about China's nuclear electrical power build-up has been published. China's nuclear power program consists of nine nuclear plants on line as of 2005 and plans to add 27 nuclear power plants by 2020 (FT 10/20/06 reports nine in operation 2 under construction and 19 in the pipeline.) China's demand for uranium in 2020 is roughly the equivalent to Australia's entire current annual exports. Australia is the world largest proved reserve of uranium and the second largest exporter after Canada. Uranium prices as that of other fuels have tripled since 2002 to about $30, but then again, according to economists, that is not a trend.

The issue of prime matter supply and reserves as related to an exponential demand continues. Even though some material resources of prime matter are almost inexhaustible (such as concrete), the mining capacity and transportation are experiencing temporary hurdles that if a rapid depletion of fossil fuels becomes a reality, will only exacerbate the crisis (being at a threshold of a catastrophe). Resources are only good if they are transported from the source to the user. In other words, the issue is messy and has many components, any of which can become critical. The demand, supply and use and the waste generated affecting the natural environment is of such scale (exponentialoid) and magnitude (Giga tons of Carbon Dioxide) that the issues move to a different level in the meta-system, unfortunately according to Palmer (2003, 2004), this higher level is one characterized by paradox and absurdities. A level where national security and the survival of a national economic system (in securing resources in normal times as well as in catastrophic times) may dictate rational or irrational behaviour.

APPENDIX B

SPECULATIVE SCENARIO: CLIMATE CHANGE PARADOX

Man-made systems have now the potential to adversely impact the meta-system called ecology (nature) that changes from a "normal" mode to a "dynamic" mode resulting in paradoxes, contradictions, anomalies with catastrophic consequences and possibly even systemic madness. The crisis and catastrophes stemming from these factors are experienced by those directly affected as terrifying events (Nicholls, 2004; Turner, 2005). Those experiencing these catastrophic events are a mixed group of victims and innocents that may be removed in time and place from the perpetrators (Parry et al 2004; Parry 2004).

For example, current scientific understanding of the effects of Carbon emissions (Grübler 2001) points to a temperature[138] increase at a global scale (Halweil, 2005). The seriousness of the global situation is captured in the warning that Britain and the Netherlands shared with the EU at the Finland Summit on 10/20/06 by stating: "We have a window of only 10-15 years to take the steps we need to avoid crossing a catastrophic tipping point."

The temperature increase is apparently affecting the melting of the polar caps (IISD, 2005a; McCarthy and McKenna 2000; Vinnikov et al. 1999 and 2000), the retreat of glaciers (Speth 2005), differing patterns of desert increase and rainfall across the globe and other issues such as an earlier spring and late fall throughout the hemispheres. The change in the duration of seasons, specifically the lengthening of the spring, summer and fall seasons was hoped to provide an increase of planet's ability to absorb Carbon Dioxide (Levy, et al. 2004; Broecker

[138] Lane et al. (2005) report that Global average surface temperatures have increased by 0.7ºC since mid-1800. The European Union is trying to keep the maximum increase in global average surface temperatures to 2.0ºC

1997). However, the rapidly increasing de-forestation[139] (for example in Brazil and developing countries clearing of forests for farming and housing with a reported 400 Million metric tons (Mmt) of carbon emissions, now ranks No. 3 behind China's 761 Mmt No. 2 and US 1,529 Mmt) is negating any increase in forest by rainfall.

The magnitude of the emissions has crossed the threshold of the natural environment increased consumption of CO_2 through forest growth partially caused by an increased in precipitation. On the other hand, the melting of the polar caps,[140] scientist predict, will change the ocean's underwater currents creating a propitious environment of much colder temperatures in the upper Latitudes (Broecker 1997). Much colder temperature in the upper latitudes, when combined with the increase of moisture and humidity due to much warmer temperatures in the tropics is a paradox - the beginnings of a dynamic, oscillating mode that could run out of control[141]. The paradox is highly complex and full of unknowns. For example, although higher temperatures imply more humidity in the air thus higher rainfall, the increase in air temperature is actually causing draught, according to the Journal of Natural Science, an unexpected condition.

Air temperatures have risen 6°C above their long term average and rainfall at half of the

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139 Atlanta, according to Raven and Berg (2004), has been clearing an average of 500 acres of wooded land each month.

140 According to Sagar et. al. 2005 (quoted by Speth 2005), temperatures have increased 0.7°C since the mid 1800. "The feeling is that if things are getting bad, you hit the stop button. But even if you do, the climate continues to change" says Gerald Meehl of the National Center for Atmospheric Research in Boulder Colorado. Even under the most optimistic emissions scenario, global temperatures will continue to raise by up to 0.6°C over the next 100 years. "Glaciers are retreating in the Andes, Alps, Europe and the Himalayas due to higher temperatures and reduced snowfall," according to European Scientists. A precise threshold beyond which "dangerous interference" with the climate system could occur has not been defined. Bill Hare of the Potsdam Institute for Climate Research in Germany warns that the European Union target of restricting global warming to 2°C (if that could be done) may even be too high in the long-term."

141 The International Panel on Climate Change (IPCC) suggests that climate change could trigger 'surprises.' These are fast, non-linear climate responses, thought to occur when environmental thresholds are crossed and new harmful equilibriums are reached. Such surprises are likely with climate changes because of the complexities of the

long-term norm. Climatologists say climate change will bring an increase and frequency of heat-waves. Previous models of climate change had assumed a doubly beneficial effect from plants growing faster under warmer conditions while there was more CO_2 and moisture. Greater plant growth means that plants are removing more carbon dioxide from the atmosphere (see *Fig. B.1* - Sterman's DICE Carbon Cycle model). This would have lessened global warming over time. The heat-wave study follows experimental results from the US that show plants do not grow faster when there is more carbon dioxide in the atmosphere during heat waves, another paradox. Scientists will have to revise their predictions of the likely severity of the effects of climate change. Another study at the Britain's Cranfield University found an unexpectedly large amount of carbon dioxide was released from the soil under warming conditions, further exacerbating the issue. Again these studies point to the complexity and integration of the systems in nature, adding to the "mudding" of the topic.

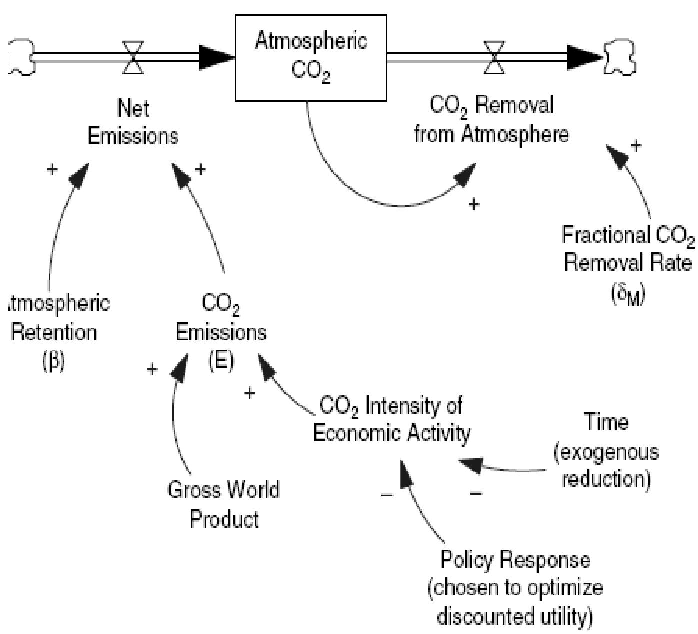

Fig. B.1 Carbon cycle in the DICE model (Nordhaus 1992). Atmospheric CO_2 is defined as the excess above the pre-industrial level

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processes and the interrelationships involved (for example between oceanic, atmospheric and terrestrial systems and our insufficient understanding of them individually and collectively.

How this paradox ends up adversely affecting the weather and global climate is the ongoing study of intensive computer simulations, beyond the scope of this work. When these models of the future appeared several years ago, there was an ambivalence of whether the south of the United States would end up as a Dessert or a Rain Forest. For example, cutting 22 billion tones of CO_2 by 2050 only gives us a one in sixteen chances (based on 6.9 Gigatons of annual emissions) of achieving the target of limiting temperature increase by 2°C and avoiding the 3°C scenario where "serious risk of large scale, irreversible system disruption" threshold was estimated by the International Scientific Steering Committee (IISD, 2005a).

However, as previously indicated we have reached 28 Gigatons of yearly emissions in 2005 and scientists are at a loss of how this unexpected magnitude translates into actual global warming and climate change. Emissions permits trading have picked up considerably in 2005, however the jury is out on whether the effort has the magnitude required to not only reach artificial sustainability or even more reduce the yearly emissions as hoped. McKibben (2006) quotes James Lovelock "we have already added too much CO_2 to the atmosphere and that runaway global warming was inevitable." McKibben continues quoting James Hansen, a NASA climatologist saying that "the instability of Greenland's ice shelf showed that we can't let it go on another ten years like this." If we did, over time, "the build up of CO_2 emissions would imply changes that constitute practically a different planet."

Some scientists hold an opposing view stating that, we have been stable for thousands of years, change as we have experience is in geological times, the best that we can expect is a dimmer-switch slowly turning… the speculative scenario that some have pointed bring the geological time to a decade or two, more like a switch. The switch model, in this hypothetical case is throwing up natures' 'break circuits', circuits which by the way we have no idea of how they work (other than speculation, such as the one of the gulf currents above mentioned but profanized by Hollywood) nor do we have any idea of how to set them back or how long will it take for them to be set back or what mechanisms are needed by nature to set them back.

What makes this scenario worse is that in the years to come, approximately around 2050 we have the possibility and/or probability for coalescence of several forces, ingredients for a ‘perfect storm’: Around that time we should be running out of ever more expensive fossil fuels and prime minerals, be generating trillions of carbon monoxide and other compounds in the air, yearly, have increasing the rate of catastrophic related weather events and a society that has no alternative but to dramatically change paradigms.

APPENDIX C

CLIMATE CHANGE AND LEGAL PRECEDENCE

Climate change is becoming a hot topic in class action suites accentuating the seriousness of the situation, the popular understanding of the personal implications both financially and legally and adding the possibility of additional complications and burdens to the general economy. Climate change – drought, rising seas and other disturbances caused by the emission of greenhouse-gases is the next frontier for class action litigation, pending several US and UK cases' outcome on whether a court is competent to rule on such cases and what kind of evidence are judicially acceptable. According to Speth (2005) the principal response of the international community to global-scale environmental challenges to date has been a legal one.

The outcome of these cases could establish precedents. The blame question remains unsettled but the scientific hurdle has shrunk as research has increasingly documented the link between bouts of extreme weather and rising greenhouse-gas emissions, a sobering historic trend for all stakeholders. In the area of Law, William Ruckelshaus (the first EPA Director) established the precedent of aggressively going after the polluter. According to Norton (2005), Ruckelshaus developed a reputation and history of nailing polluters in complex enforcement actions by taking them to court. In the first sixty days of its existence, EPA enforcement officers brought five times as many enforcement actions against polluters as been brought in a similar period by the precursors to the agency.

Chemical water, air and ground environmental pollution is now augmented by the arguments for the effects of pollution, climate change, and devastation through catastrophic events. The link between these three elements may prove to be more tenuous and tortuous to establish as the link between smoking and lung cancer, a hurdle that ended in forced negotiations. As long as there is a smoking gun and a silver bullet, with a deep pocket target, there will be cases. But what may end up being tried in court is not a company, a series of offenders but our common way of life, like Dr. Seuss saying, *I meant no harm. I most truly did not. But I had to grow bigger. So bigger I got.* If this is the case, and suspect it is, then the working paradigm of humanity (conspicuous consumption) is figuratively on trial.

According to Kuhn (1976), we can not abandon a working paradigm until a replacement is found, and this appears to be the source of our collective dilemma, one where tactics of delay, feet dragging, opposition, and lack of theories, appears to be reigning while at the same time feverish work is taking place at all levels of society to get a handle on a working language such as that exemplified by the concept of sustainability. Without that language there is not a chance for trial, even though science has moved from the need for having absolute certainty about the cause and effects to a position that the criticality and magnitude of the problems indicate action.

Controlled experimental action is in order with the hopes of uncovering what was previously termed invincible ignorance (ignorance of ignorance, closed ignorance) and moving towards vincible ignorance (accepting that we are ignorant, open ignorance) and further on towards humble knowledge. The rationale behind this is based on the grounds that our past solutions, masked in promises that have delivered great progress, have also brought our current untenable condition. Any steps towards a solution has to be carefully screened to pass the test of the exponentialoid, that is how will it play out when reaching the larger growth, size or sheer numbers.

The issues are so muddied by the paradigm shift that even Philosophy, Theology and Medicine can not support a position even if law finds the practices of humanity guilty of producing the current waste that pollutes the environment that changes the climate that generates the catastrophes that affect the lives of people. The present condition is unlike that at the time of EPA where there was a clear backing from the major areas of knowledge: Philosophical (scientific) paradigms defining pollution and (historical) linking events and illness or mortality, Theological paradigms regarding the sanctity of life, and Medical paradigms (linking pollution and illness or mortality) which made the law easier to apply in force and change the industrial paradigms of economy, efficiency, risk, etc…In-depth treatment of the relation of legal issues and the environment is subject for future research.

APPENDIX D

PHILOSOPHICAL BACKGROUND OF FRAMEWORK AND SCHEMA FOR CREATING A WORLDVIEW OF THE INDUSTRY

To ‘cause’ is a necessarily explicit function: A causes B, B is caused by A. There is an immediate contradiction if we say that A causes A or A causes itself. What we can say is that A appears by itself, from itself and in itself (Heidegger 1954). These two aspects of causality point to two types of sciences, on our way to an understanding of a ‘hypothesis’ in this dissertation: (1) “A” by itself – science of understand of things or aspects with extra-causal patent (pure phenomenological type) and (2) “A causes B” – science of things, objects or aspects with causality or action (physical, real type). According to García Bacca (1963), real causes (2) have to end in phenomenological types (1). “A causes B”, according to modern physics, is distinguished by scalars (magnitudes) or vectorials that besides having magnitude have a proper direction as well as sense. “A causes B” is a relation uncovered through the lenses of a schema that is able to connect the phenomenological “A” with the scalar or vectorial “B”.

When a categorical frame or schema is uncovered (discovered) according to aspects of reality, a new field or background becomes highlighted. These fields or backgrounds manifest themselves in logical propositions that appear to speak to us in a language (symbol and meaning a la Popper 1959, 1972) that can be understood without destroying the reality of itself and the reality of the frame or schema. Some of these frames or schemas allow the perception of the universal, a categorical objective cosmic plan. Real causes and consequences can then be un-coupled from the phenomenological aspects and the frame/schema with total inconsideration, according to García Bacca (1963). The categorical plan “A”, phenomenological, frame/schema is one in which objects (things) talk-but-do-not-act. In contrast, the categorical plan "B", causes and consequences, frame/schema is one in which objects (things) act-but-do-not-talk.

The two categorical plans "A" and "B" appear as ontic frame/schemas that are inclined towards different and distinctive languages: "A" Qualitative (descriptive) on the phenomenological (explicative) and "B" quantitative (mathematical, geometrical, calculus, etc…) on the causal (real). The quantitative lends itself to experimentation (using Procolo's second definition of hypothesis: real cause→ hypothesis→ (Demonstration, Experimentation, Explanation) to see what comes-out when reality (objects) are caught off guard, outside their normal course, when forced by a group of fixed circumstances to manifest in the frame or schema as a force uncoupled, unlinked to their natural state. Heidegger (1954) observed that technology is a neutral means or human activity –a kind of truth revealing – that sets up and challenges nature to yield (release and transform) a kind of energy that can, at will, be independently stored, and transmitted (*distributed*).

However Bacon, as quoted by Mitcham (1994), issues a word of caution: "The search for final causes is condemned to sterility like the virgins consecrated to God". Our current hypothesis is not a search of final causes, in contrast with Hawking's (1998) search for a unifying theory of the cosmos. Starting with an observation of causes and consequences a hypothesis is made with a sensitive frame or schema in mind as a way of capturing the real as it manifest in-itself from the background or field. The sensitivity to the understanding of the spatioloid and temporaloid characteristics of what is being observed allows us to join Newton and state 'hypothesis non figo' we are not feigning a hypothesis. To be interpreted as: our hypothesis is simply adjusting to the properties of things, objects, conditions, and is not trying to determine them. This dissertation, a pre-paradigmatic work, makes no pretense at being precise, the emphasis is on broad orders of magnitude and more importantly, on the appropriate philosophy, worldview and methodology for framing complex problems.

From this relative space and time of causes and consequences in nature[142], through the study of the scalars (magnitudes) and when possibly the vectorial forces (magnitude, sense and direction), we present with our frame and schema a mirror to capture the object as it occupies a place in movement or no movement (in vulgar time or duration). For example $F = m*a$ has the absolute, real and efficient cause that is universal, supra-individual and supra-specific of "F" in an equal (=) relation to "m" and "a" which are a real substitute or surrogate of material cause that is individual as well as of-any-object[143]. "F" belongs to the ample universality of pure aspects in a cosmic state that is supra-individual and supra-specific (Laplace, Poisson, Einstein, Hawking, etc…).

The universal "F" also contains the potential and is external and cosmic in that it is pre-existent to the external manifestations of the individual and particular "mass" or "acceleration". Mass "m" and acceleration "a" by being temporal and transitory will revert back to the cosmic state of "F" which is more stable and primary than the individual state. In this case "m" tends to speak in terms of the characteristics of space, that is, spatioloid; while acceleration "a" tends to speak in terms of the characteristics of time, that is, temporaloid. The mass and acceleration are individual, temporal and transitory, furthermore "m" and "a" belong to a scalar field if it only posses or presents a 'magnitude' and to the vectorial field if it posses or presents characteristics with a 'magnitude, sense and direction'.

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[142] Hawking 1998: Space-time are dynamic quantities in that they not only affect but also are affected by everything.

[143] Another famous equations with universal and scalar components: Faraday, M., (1791-1867) discovered the electricity and magnetism; Maxwell, J., (1831-1879) the theories of energy; Lavoisier, A., (1743-1794) the concept of mass through chemistry; du Châtelet, E., (1706-1749) the v^2; Roemer, O., (1644-1710) the speed of light; Einstein, A., the final formula $E=mc^2$ where the speed of light is the only constant.

It is in this understanding or frame that we are approaching the phenomenological, as well as the causes and or consequences uncovered in this dissertation, with the hope that in our frame or schema the link between the real and the universal, absolute, will be manifested.

The frame or schema is the transcendental mirror of Heidegger (1954), which gives access to the 'field' so that things-in-themselves show up or appear or are given to us (which are a condition of the possibilities of experiences) with objective aspects that we may be able to interpret with the respective and appropriate language. Therefore this dissertation is bilingual in the sense that we will use philosophy's phenomenology (Embree 1996) and hermeneutics when dealing with the was-sein as well as mathematics, geometry, calculus when required as in dealing with the das-sein.

However, we are aware there are no assurances that because there is a possibility of an experience that links the real with the universal 'can', 'must' or 'will' be manifested. In other words, there is NO assurance that the links with the real can be forcibly obtained. These revelations are not pre-determined but from the realm of possibilities they pass to the realm of probability as in quantum theory. Quantum physics according to De Broglie (as quoted by García Bacca 1963) is based on two principles: (1) the first principle informs of the 'possible' values that has at least scale (magnitude); (2) the second principle gives us, afterwards, the probability of such possibilities. The possibilities of a physical experience and of its objects wait for the showing of things, knowing that 'if' of 'iff' (also known in calculus as conditional "if", that is, 'if and only if') they are shown, they will have to present themselves as objects, as objective images NOT in the mirror of conditions of possibilities, but on a more sensitive and sensible mirror of possibilities with a degree of probability.

If things are given as 'necessary' by internal law, that is they must manifest themselves as they are in-themselves completely and without reservations, we would simply need to offer them a mirror of the conditions of possibilities and the order of the modalities would be assumed to be correct, complete and consistent (see *Fig. D.1)*:

possibility → real physical → physical necessity
Fig. D.1 Partial modalities of experience

In this case the 'necessary' internal disclosure removes the need of the 'probability' modality since probability is the original mode and property of the contingent. However, according to Planck, between the real physical and the physical necessary we suspect that a mode of probability is inserted or embedded that converges towards necessity with the small barrier of what Planck has called his constant (see *Fig. D.2)*:

possibility → real physical → probability → physical necessity
Fig. D.2 Modalities of experience

What does this means in terms of this dissertation? Firstly, it means that there must be a possibility of discovering a relationship between information that has been compiled and some meaning (schema) of the physical reality that is highlighted by a physical necessity, which in our case are the challenges. Secondly, that the relationship is observed through a "worldview" that needs to be created, if it already does not exist, based on some primary elements of a framework. This brings us to the more remote elements of a framework, which in our case are "schemas", as a means of reaching out into the world of the cosmos, the universe of phenomena, for the links between elements primarily through meaning, qualitatively, phenomenologically.

Once these elements are identified we are in position to develop the instruments that analyze, interpret the correct, complete and pertinent data to verify the current industry's sense, magnitude and direction and project what changes need to be made that will result in an industrial vector that addresses environmental compatible sustainability.

APPENDIX E

SCHEMAS THAT INFORM THE PROPOSED WORLDVIEW OF THE BUILDING CONSTRUCTION INDUSTRY

Two schemas are identified to inform a worldview of the building construction industry. *Fig. E.1 Schema of macro-issues* is mainly an internal industry schema used to generate the worldview of the industry. The General Schema (*Fig. 4.4*) is primarily an external conception of ontic relationships from Palmer (2004) adapted to the artificial (built) and natural environment as a bridge for understanding how the two relate.

The first schema of macro-issues is derived from extensive literature search of the ordering, relations and nesting of the issues of response, change and systemic nature of the industry. Glimpses of the elements of this schema are dotted in literature, but literature search indicates that it has not been found or presented in the current format. For example, a list of stakeholders in the industry is well known; the relationship of needs and wants has been studied sociologically and philosophically; an industrial response can be glimpsed through studies of the Industrial Revolution and the current trends and initiatives in the industry exist in published research; the mechanisms for change, capacity for change the systemic nature of the industry are areas not well defined at the present time. A worldview of the industry can be likewise glimpsed from the current research trends and from historical precedence, although it is not well articulated, as in other domains and industries. The universe of issues is the background on which the industry exists, draws its initiatives and challenges and ultimately deposits its contributions and problems but this universe of issues has come under scientific observation rather recently and discoveries are nascent.

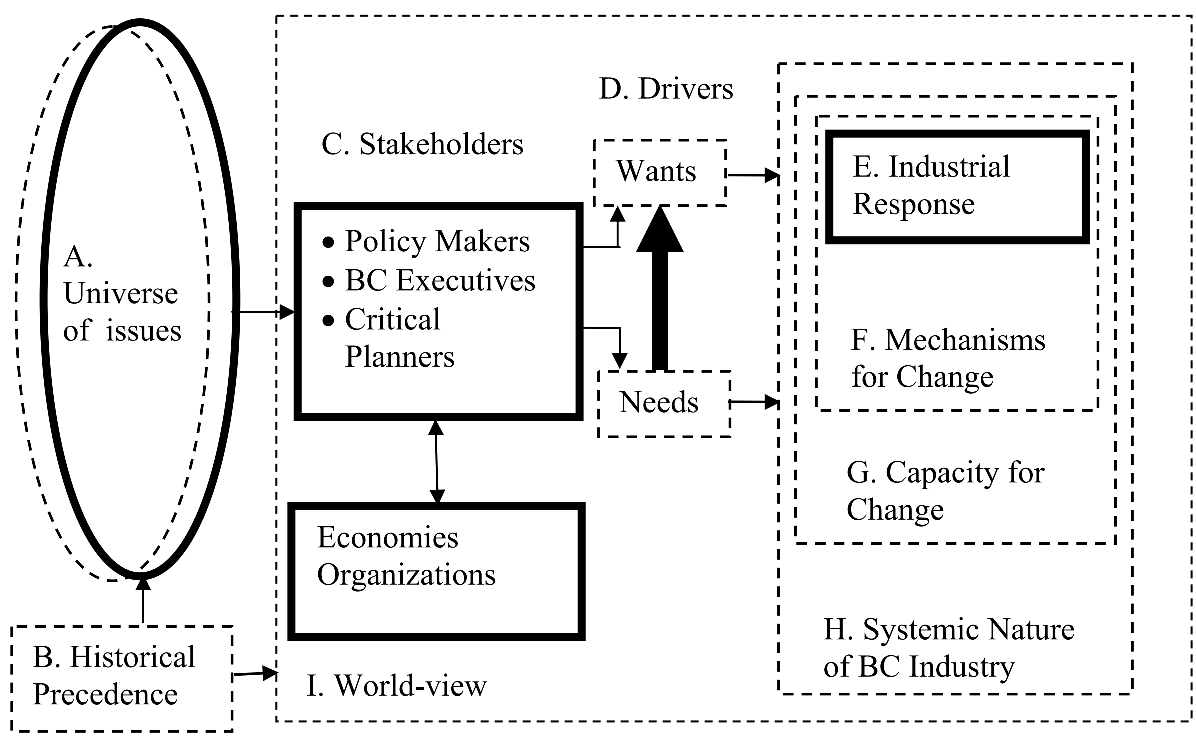

Fig. E.1 Schema of macro-issues. Dashed = embedded

The second schema, the General Schema theory (*Fig. E.2)*, as previously mentioned, provides a conceptual framework that articulates relationships and linkages among elements of the universe world of reality as envisioned by Palmer 2001b, 2004). This schema then becomes the backbone upon which two additional schemas are coupled: The artificial (built) and the natural environments. Of particular interest to both the artificial and the natural environment is the notion of meta-systems. In this schema conception, for example, a building, as an artificial meta-system is composed of systems (such as structural system, mechanical systems, electrical systems, etc…), which on their own are complete and independent systems that come together to form a system of systems, in a building.

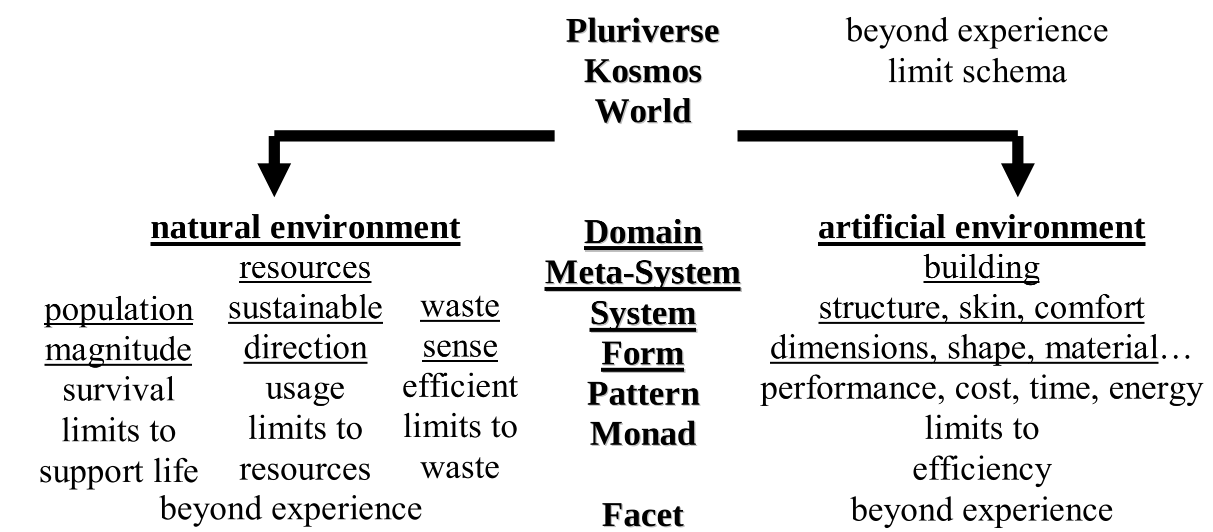

Fig. E.2 *General Schemas Theory"* Adapted from Palmer, 2001, 2004, Ontological Hierarchy in "*General Schemas Theory" See http://holonomic.net* , *http://archonic.net*

However, as Palmer (2004) describes this system of systems or meta-system by its own nature has interstices or holes which make it like "an organic" system of interrelations and ontic in nature. The contrast of a meta-system and a system is that although a system can be optimized, the meta-system by nature contains paradoxical elements that prevent optimization, such as Lauri Koskela's (2000) observation of on site, one of a kind, by differing teams.

These two schemas and its interpretation (see Table E.1) create the framework for understanding the proposed worldview of building construction industry. In the historical analysis that follows, for example, iron (cast, and wrought, and eventually steel as a structural system were developed independently from building construction originally for the manufacture of machines such a as locomotives and railroad tracks, as was the Air condition for making ice and Elevator system for vertical conveyance of textiles materials and products. That these first time technologies (inventions) found a place and evolved through other than first time technologies (innovations) in the building industry is fortunate, but not deterministic as we shall see later on. Such meta-system is the background that informs the building industry, and we propose, a key component for understanding the systemic nature of the industry.

In this chapter we identify the industry in this we will look at a period in history where significant changes occurred in the four identified phases of the Industrial Revolution. Furthermore, the Industrial Revolution is the background where inventions, technologies, etc… originated and matured as whole systems, usually intended for other industries as we have briefly pointed out, but when adapted to building construction allowed the high-rise building type, a project as a meta-system (system of systems) to evolve.

The analysis of the high-rise building, as the analysis of the Industrial Revolution is focused on the elements, actors that propitiated its advent and evolution. For a more granular (detailed, defined) inspection of these elements, we will look at two of the systems that are part of the systems-of-systems of the high-rise building, air conditioning and elevators, for the elements that propitiated their invention and evolution. In summary, the Industrial Revolution, high-rise building, air conditioning and elevator are surrogates from which a list of actors, elements of change is generated.

Table E. 1 Nesting of Schemas by Palmer (2002)

From Palmer (2001) on the Nesting of Schemas:

Pluriverse: Deutsch, D., *"The fabric of reality,"* The Pluriverse is the intersection of all existing universes. This schema is beyond our experience.

Kosmos: Or Universe, subject of scientific exploration. Thales and Anaxamander (Metaphysics). . This is upper bound the limit of our direct experience. . Kosmo of Kosmos = Pluriverse

World: The coherence of everything we experience; Defined by Heidegger as the furthest horizon of our direct experience. Husserl calls that Lifeworld. World of worlds = Kosmos.

Domain: Disciplines that have different perspective on phenomena. Domain of domains = World

Meta-System: Also called Open-scape or Proto-Gestalt. It is comprised of contexts, situations, milieus, environments, ecosystems, etc. They are fields within which systems arise and interact. They represent a whole less than the sum of its parts. Meta-system of meta-systems = Domain

Systems: Perceptually this is the level of the social gestalt characterized as a whole that is greater than the sum of its parts composed of figure and ground. Usually defined as a set of things and their interrelations or interactions. But this definition is analytical and does not account for the wholeness of the system. See Rescher *"Cognitive Systematization"* who considers the organic metaphor that grounds our idea of systems. System of systems = Meta-System

Form: External shape of an object. This level includes not just the external shape but also its behavior as in object oriented design. Form of forms = System

Pattern: Value, Sign, Flux and Structure are various kinds of patterning of content. This is the lowest level of our experience and is dependent on the lowest level of articulation by our instrumentation. Pattern of patterns = Form

Monad: The datum of the content itself at whatever level of resolution. This is the lower bound limit of our direct experience. Monad of monads = Pattern

Facet: Beyond our direct experience. It is an inner determination of differences within the phenomena itself, seen within itself without the projection of our schemas. Thus this is the null schema. It is the difference beyond the resolution of our instruments. Facet of facets = Monad

APPENDIX F

THE FIRST INDUSTRIAL REVOLUTION (I-IR, ca. 1700 – 1850)

The 1-IR in Europe consists of inventions, innovations and a series of changes that generated further changes that are well documented and researched. Several key topics (Demographics, Climate Change, Social Attitudes, Entrepreneurship, Organization, Technology, Inventions and Innovations, Regulatory Framework, Economy, and Education) appear with frequency in the literature surveyed (Landes 2003; King and Timmins 2001; and others as cited). These topics have been condensed for comparative analysis during the differing IR phases to identify the elements that have influenced the evolution IR, population growth, and by extension the building construction industry.

This analysis relies heavily on Landes (historical), King and Timmins (historical-economic) and their citations, as world renowned experts in the field with their work considered by others as exhaustive commentaries of the times.

Demographics

On the eve of industrialization, economic growth as it did take place was translated into population growth: Increased income meant better hygiene, affordable medical services, better nutrition, better housing conveniences, etc that translated into lower death rates and in some instances higher birth rates. "The larger numbers initially either ate up the gain or outstripping it", set the stage for what is known as Malthusian Positive Checks (see *Fig. 4.3 and 4.4)*.

Climate Change (as an actor of change)

The 1700's is also the end of what is known as the little ice age[144] that lasted approximately 400 years (Landes 2003), and according to scientists was caused by two main factors: world-wide volcanic eruptions and an unprecedented extended solar minimum (see *Fig. F.1.*)

The end of the little ice age (scientist attribute this phenomena mainly to two causes: Increase in sustained volcanic activity and the Solar Maunder Minimum – decrease of solar activity for an extended period) saw an increase in agriculture production due to the relative warming trend. In this particular case Climate Change is a generator of change, that in human terms were beneficial. According to Landes (2003) and King and Timmins (2001) from the year 1000 to the 1700's agricultural income per head in Europe rose appreciably, perhaps tripled, and this accelerated sharply in the 1700's[145].

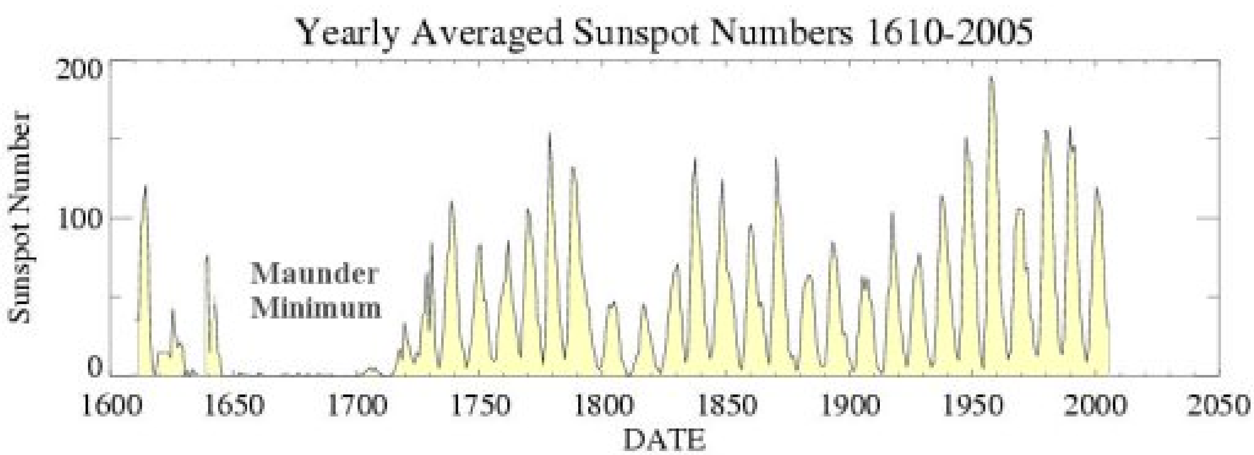

Fig. F.1 NASA Solar Flares and the Maunder Minimum (Little Ice Age)

[144] The last Ice Age, according to archeologists, ended about 10,000 BC as quoted by Hawkins 1998.
[145] One of the best signs of comfort in Europe is the consumption of white bread per capita which parallels the rise per capita of income and the diffusion of living standards.

This extra income set the stage, along with changes in government[146] (freedom, security), social values (private property, entrepreneurship, commerce) and a Faustian attitude of mastery over man and nature, rationality (the adaptation of means to achieve ends), technological advances (resource extraction and manufacturing, creative tinkering, a nascent science and creativity), knowledge transfer (apprenticeship, guilds, division of labor, discipline), economy (banking, performance, risk transfer) and urbanization[147] (population concentrated in cities) that propitiated what is now termed the First IR (1700's – 1850).

The following is an example of the growth undertaken during this phase of the Industrial Revolution: in 1760 Britain imported 2.5 M lbs of cotton, in 1787 cotton consumption reached 22 M lbs and in 1837 consumption increased to 360 M lbs (Landes 2003). Such raise in consumption, exponentialoid[148] in nature, had not been achieved previously and most historians link it to a raise in agriculture and the start of industrialization.

Climate change is one of the factors in the shift from heavy wool to the preferred lighter cotton fabrics with a substantial increase in demand. Cotton[149] manufacture saw the price of yarn fall to 1/20th of 1760 levels, allowing British yarns to be sold worldwide[150] giving raise to the British industrial proletariat with disposable income. This increase in production displaced established methods, damaged vested interests and was made possible by: (1) an opportunity for

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146 The issue of central versus fragmented authority had been settled in favor of the former except in Germany until the mid 1800's. A standing bureaucracy administering a known corpus of law and separating the function and prerogative of office from personal interest worked to varying degrees.

147 England had more people living in cities than any other European country, except perhaps for Holland (Landes 2003). Industrialization was a magnet for urban living. However Holland population was declining sharply at that time (Petersen, 1955) both absolutely and relatively given the constraints of space – very limited land area.

148 The term exponentialoid is used to denote a vectorial force with logarithmic magnitude and direction with multiple and complex sources.

149 An increase in cotton acreage was far more rapid than an increase in sheep for wool. Cotton introduced a new kind of clothing tough, yet comfortable to the skin, easy to clean and maintain and able to made colorful.

150 The effects of export was to reinforce the pressures towards standardization, more on this later, as against differentiation, quantity as against perceived traditional quality such as wool versus cotton, coal in place of wood in breweries.

improvements due to the inadequacy of prevailing techniques, or a need for improvements created by autonomous increase in factor costs, (2) a degree of superiority (value) such that the new methods pay sufficiently to cover the costs of change, even though the users of older less efficient methods attempted repeatedly to survive by compressing the human factors of production, entrepreneurial and/or labor.

Progressive producers had to out-price and displace the traditional methods resolutely thus revising the concept of risk. For example, where before the costs of manufacture had been variable – raw materials and labor primarily – more and more would now have to be sunk in a fixed plant, thus the concomitant boom in building factories[151], that is, fixed plants and machinery; Whereas before labor could be downsized or dismissed according to decrease in demand, now the entrepreneur became prisoner of the fixed investment. Labor is active, it is not a factor like technology, equipment or materials which are passive.

Social Attitudes

Labor has a mind of its own; it resists as well as responds; its performance is independent of other considerations – what we may call its efficiency as opposed of its productivity – is not easily calculated and the historical data is correspondingly impressionistic and sparse. It is especially difficult[152] to separate pure effort, diligence, and skill from organization and supervision. Analysis of the early part of the Industrial Revolution shows a backward-bending supply curve that had always characterized domestic work**.** Just as 'wastes' tended to be

[151] Factories are characterizised by: concentration of production and maintenance of discipline regarding presence, precision and regularity of functions.

[152] Our ignorance of the variations of labor efficiency over space and time is more unfortunate because Landes observes we have every reason to believe that it is was an important determinant of the rate and character of economic development in any given country and as between countries; moreover this was one of the areas of greatest slack and by the same token, of greatest potential gain in productivity.

customary, so the level of performance was fixed by tradition and income expectations, 'a fair day's work for a fair day's pay.'

The impasse was partially broken when management achieved the right to shift men about as needed, that is, to treat the worker as an interchangeable part of the production process, where replacement of skilled by semi-skilled or unskilled workers by the insertion of machinery, allowed the pace to be set by management from above. Homogeneous units of output provided the structure to measure routine operations of special-purpose machines and time wages gave way to piece wages[153].

Entrepreneurship

The hallmark of British entrepreneurship was to supervise their financial affairs closely, like the opening of mines, building iron works, digging canals, developing ports and leasing urban property for building. what is more they anticipated demand, undertook investments on speculation, advertised if necessary for tenants, enclosed the land[154], concentrated their holdings in a society that imposed relatively few institutional barriers. Private property, freedom to capitalize and competition conferred on innovation and the pursuit of wealth as a way of life.

In contrast, France's family[155] run business was almost always closed to outsiders while British entrepreneurs were far more willing to enter into association with friends and friends of friends based on diligence, thrift and rationality (means to an end). In France, commercial enterprise had traditionally entailed derogation from noble status, even though the monarchy

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[153] However time wages allowed an imperceptible productivity increase whereas piece wages was interpreted to be and instrument of exploitation and new rates of production were rarely maintained beyond what was felt to be reasonable increases over customary wages.
[154] Land enclosure is termed as the Agricultural Revolution (Pell, 1887).
[155] In France, the Low Countries or Germany the business firm was almost indistinguishable from family. This led to a premium on security, an overestimation of risk, a policy of pricing that maximized the unit rather than the total profit, and a reluctance to borrow except *in extremis* (Landes, 1949).

made repeated efforts to make trade and large-scale manufacture compatible with aristocracy. In Germany the cleavage was reinforced by laws (see Regulatory Framework, in this Appendix).

Organization

Landes (2003) and King and Timmins (2001) state that the Industrial Revolution brought about discipline and supervision in the *organization* that produced a 'concentration' of manufacture in England that supplanted handicraft in shops and cottages with the mill and the factory workshops. The organization shift to a manufacturing locale required improvements in getting and working raw materials (mainly in the nascent metallurgical and chemical industries) and the systems of production required the differentiation and specialties of functions and responsibilities.

England, by having a period of internal and external peace, abundant agriculture during this time, and openness to private property and freedom of work along with a compact land mass dotted with abundant mineral sources and transportation via open water and canals, had the fertile ground for something to happen. France has considerable more land but with more difficult terrain which made for higher transportation costs, navigable rivers that were frequently either too dry or too fast, fragmentation of the markets and longer and less kept roads than Britain. Landes observes that propitious terrain and transportation channels, changes per se in organization, or having the fertile ground, did not create the Industrial Revolution.

Technology

The heart of the Industrial Revolution was an interrelated succession of technological changes. The material advances took place, according to Landes (1969, 2003 - 2nd Ed.) in three areas: (1) a substitution of mechanical devices for human skills[156] (other call it a magnification,

[156] Apparently "it is easier to make machines work like man than man to work like machines" (Landes, 2003).

augmentation of human skills through mechanical devices); (2) inanimate power increases (wood to charcoal to coal) – in particular steam generation – that took the place of human and animal strength; (3) a marked improvement in the getting and working of raw materials, especially in what are now known as the metallurgical and chemical industries.

Inventions / Innovations

Inventions, pathways to efficiency, came in a sequence of (1) challenges and response in which the speed-up of one stage of the manufacturing process placed a heavy strain on the factors of production of one or more other stages and call forth innovations to correct the imbalance. (2) The many small gains[157] were just as important as the more spectacular initial advances.

Challenges and response: Inventions and later on innovations (improvements on inventions) in metallurgy allowed the emergence of technologies for the make and use of tools and machines to create products. One of the primary stimuli of modern technology is free-ranging imagination; the increasing autonomy to accumulate a pool of untapped knowledge whether via tinkering, the work of savants or science[158] in combination with the ramifying stock of established technique that gives ever wider scope to the inventive vision. Free-ranging imagination is encouraged by the possibility of proprietorship of the invention in terms of patents and royalties which bring us to social values.

[157] Some of the small anonymous gains are better materials, closer tolerances, the introduction of safety valves and gauges in steam engines, the recognition and adoption of coal specially suited for the different applications and the collection of accurate information on the performance of engines under different conditions, improvements in tool designs, a shift from tinkering to science such as thermodynamics based on empirical observations of engineering methods and performance, down to the standardization of nuts and bolts in manufacturing allowing interchangeability at a national and eventually multi-national scale (although the metric and imperial systems testify otherwise).

[158] Fairbairn (1864) observes that even the ordinary millwright was usually 'a fair arithmetician, knew something of geometry, leveling, and mensuration, and in some cases possessed a very competent knowledge of practical mathematics. He could calculate velocities, strength, and power of machines: could draw in plan and section…' attainments due to abundant facilities for technical education in villages like Manchester. These were attended by visiting lecturers, 'mathematical and commercial' private schools with evening classes, and a wide circulation of practical manuals, periodicals and encyclopedias.

Spectacular advances: By introducing a refinery hearth and sometimes also a reverberatory fire (one in which the flames do not play directly on the metal and cooling until the wrought iron could be separated by reason of its higher melting-point) between the furnace and the forge, it was possible to use coal or coke rather than charcoal. The operation was still slow and the resulting product not so good as charcoal bar, but it was cheaper. Henry Cort's combination of puddling and rolling (patents of 1784 and 1783) squeezed rather than beat out the dross, shaping the iron the while. This action worked fifteen times faster over the reciprocating action of the tilt-hammer; and by grooving or otherwise performing the rolls, one could now turn out an almost unlimited range of those standardized crude shapes – beams, bars, rails and the like that constitute the framework of industry, construction and transport.

The lesser improvements in iron technology were concatenated for the most part in three areas: (a) Fuel economy. Coal consumption per ton of pig iron dropped from 8 tons in 1791 to 3.5 tons in 1830 while increasing production considerably. Great Britain output of pig iron in 1740 was 17,350 long tons and 2,701,000 long tons in 1852 (Landes). In refining, traditional techniques used 2.5 – 3 tons of charcoal per ton of crude iron produced. The use of mixed fuel (part coke and part charcoal) reduced the ration to about 2-1. Puddling brought it down to 1.5 to 1 and further improvements to .75 to 1. (b) Economy of metal. Early puddling furnaces drew off half the pig in the slag. Joseph Hall's 1830 furnace bed of roasted tap cinder (instead of the iron hungry sand) cut waste to 8% while speeding the conversion process.

At the end of the nineteenth Century the waste amounted to 5%. (c) Adaptation to growth. The constant enlargement of the blast furnace was aimed, not so much at saving raw materials as at raising output, and if possible the productivity of labor. Growing familiarity with the uses of iron brought a demand for ever-larger pieces of metal. This increased the difficulties in moving the raw material and in handling and shaping the work. Various devices solved the problems: elevated platforms for lading the blast furnace, rails for transportation within the plant and the forge sheds, overhead chain pulleys and cranes to lift the blooms and finished pieces, the steam hammer (1839) placed in the hands of the forge worker unprecedented power and strength, subject to precise control and large boring machines were analogous with advance.

Other labor saving inventions were the turret lathe; the milling machine; the substitution of the rolling mill[159] for the hammer in forge work; continuous rolling for reversing rolls in the mill; the replacement of the reciprocating steam-engine by the turbine; the circular saw, rotary printing press, cylinder printing; high-speed drills; bits with spiral cutting edges instead of the traditional smooth sides; the slotting machine and others. In general, the means of performance came first; the standards of accuracy came later[160].

Great Britain in 1740 was using perhaps 10 or 11 pounds of wrought iron per person per year. In 1790 consumption almost doubled. By comparison, the French were using around 5 pounds per person per year at a latter date (Landes 2003). In 1740 Britain output of iron was smaller than that of France; by 1848 she was smelting almost two million tons, more than the rest of the world put together. British exports of iron were 57,000 tons in 1814 and 1,036,000 tons in 1852. The steam engine (grossly inefficient at first delivering 1% of the work represented by their thermal inputs[161]) and railroad extended the exponential demand of iron for fifty years.

[159] The rolling mill was developed in the USA by Armco (The American Rolling Mill Co.) in 1928.

[160] Landes observes that at this time reproduction or replacement was by approximation with the file being the most used tool. Every screw had its individual thread until Whitworth worked out standard threads for bolts and screws of all sizes and the developed the gauges that bear his name. Diffusion of these principles and techniques was another matter. Standardized precision work, which made possible interchangeable parts, preceded the adoption of common industry-wide norms, a challenge to vanity, habit and inertia to change traditional practices.

[161] By 1870 Great Britain steam engine capacity is estimated at 4 million horsepower, equivalent to the power that could be generated by 6 million horses or 40 million men. The leitmotif of steam technology was the effort to increase efficiency, that is, the amount of work performed per input of energy.

From 1870 to 1907 the capacity of prime movers in the British industry alone more than double and from 1907 to 1930 it doubled again.

World consumption of commercial sources of energy multiplied six times in the years from 1860 to 1900 and more than tripled in the next half-century. By the time of the Crystal Palace Exposition in 1851, Britain earned the title of ‘workshop of the world. Britain, with a population half that of France was turning out two-thirds of the world’s coal, more than half of its iron and cotton cloth (according to Landes 2003, the figures are approximate but furnish orders of proportion). Britain’s self confidence made the move to remove all the artificial protections of her industrialists, farmers, and shippers against foreign rivals. No other country followed suit, as a matter of fact, most became more protectionists. According to Deane[162] (1957) as quoted in Landes, in converted currency British per capita income in 1860 was about £32.6, France £21.1 and Germany £13.3. Income and wealth were more unequally distributed on the Continent than in Britain.

Even mechanization and the importance of technological considerations were not sufficient to overcome tradition in some sectors bound by social values, such as wool. For example, coal has been a necessary but not a sufficient cause of industrial performance. For example the following analogy: One cannot work without eating, yet the availability of food will not make one work. Coal and steam did not make the Industrial Revolution; but they permitted its extraordinary development and diffusion. Landes observes again that changes per se in technology did not create the industrial revolution.

[162] Reports come from published government representatives and private businesses on ‘tours of inspections’ the best sources for the industrial history of the period.

Regulatory Framework

Regarding British Regulatory framework, two classes emerged (besides rulers and aristocracy) the employer/owner and the worker/labor. The owners (that included rulers and aristocracy in England, in contrast to France where rulers and aristocracy were above entrepreneurship and commerce) were sheltered from previous arbitrary extractions, random confiscation and indemnification practices by rulers (rulers or aristocracy) through the acceptance of private property and the allowance of free enterprise.[163]

In contrast, the rulers and aristocracy in France and Germany taxed, confiscated and re-distributed property more frequently[164]. Private property and free enterprise (in England) allowed the accumulation of capital through families, entrepreneurs, government (bureaucracies or royalty) and eventually a nascent banking industry.

Economy

The banking industry of the *Economic Sector* began taking surplus capital from agriculture and made them available to the industries of metallurgy and chemistry, accommodation paper, checks (checque in French) in lieu of cash became an acceptable form for payment, and eventually a system of credit[165]. This is sometimes called the "financial revolution" within the Industrial Revolution. The financial revolution had two aspects: One was a drastic widening of the clientele for banking services and credit and the other was the institution of great branch

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[163] Especially the absence of custom barriers or feudal tolls created in Britain the largest coherent market at the time.

[164] Whenever rulers created state enterprises to promote industrialization, the products centered on stapels of royal consumption-armaments first, and then decorative furnishings like mirrors and tapestries and porcelain, developing a strong affection for the 'wrong' products i.e. imperial carpets at Les Gobelins in France, and promoting monopoly. In most cases the state run industries were an encouragement for laxity and a cover for incompetency which closed when monarchs died, a change in government personnel or an ideological shift such as *laissez-faire* cut them off from state largesse.

[165] Revolving and open credits, even standing overdrafts served in a paper instrument economy as quasi capital (King, 1936; Pressnell, 1956; Landes, 1958).

banks that brought the country and the city together in a circle of mutual assistance and reinforcement. Multi-national economic transactions were instituted; companies could raise capital through stocks based on perceived value that included cost of resources and the price of labor which was related to the availability of the population. Population growth[166] and the freedom from needs allowed commerce to thrive and wants became the demand driver paralleling that of population. The first industrial revolution centers in particular on the movement of labor and resources from agriculture to industry.

The shift reflects the interaction of enduring characteristics of demand with the changing conditions of supply engendered by the industrial revolution. On the demand side, the nature of human wants is such that raises in income increase the appetite for manufactures. People living on the borderline of subsistence may use any extra money to eat better. But on the eve of the industrialization, people in Europe were living above this level and as income went up, their expenditures on manufactured goods increased even faster. On the supply side, this shift in demand was reinforced by the relatively larger gains in industrial productivity against agricultural productivity, with a consequent fall in the price of manufactures relative to that of primary products.

The supply quickly overgrew the national demand, and commerce expanded to other nations and colonies. In the beginning abolition of tariffs and the opening up of commerce between nations created an unprecedented demand that was curtailed by latter protectionism, mostly during the second industrial revolution. Again, even though social values did not create the industrial revolution it was certainly a modifier, sometimes accelerate and other times decelerate the demand that influenced the magnitude of the revolution.

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[166] Duane and Cole (1962) place British population from not quite 6M around 1700 to almost 9M in 1800 with 70 to

Capital formation in Britain (Duane, 1961) did not go above 5 or 6% of GDP throughout most of the eighteenth Century raising later on to 7 or 8% and reaching 10% during the railway boom of the 1840's. France (Markzewski, 1963) net rate of 3% lasted until the railway boom when it rose to 8%. For Germany the data is non-existent prior to 1850-1870 when it reached an average less than 10% (Kunets, 1961).

Change begat change. Technical improvements were feasible only after what Landes calls 'autonomous'[167] advances in associated fields. An increase in agriculture, especially in England, along with a relatively stable and safe society originally generated excess capital and a population increase that translated into available manpower. Idle agricultural manpower became a source of the homegrown wool and cotton industry. Idle agricultural capital got invested into coal mining as a substitute for wood, charcoal and water (hydraulic) for metallurgy, a godsend to the iron industry that was stifling for lack of fuel[168]; Coal was a cheaper, apparently inexhaustible (when found) and better energy source in terms of power generation ease of extraction and use (and initially contributed to the chemistry of iron itself).

Coal was a better value for the cost of extraction and the price of labor and profits than wood, charcoal and water in England (relatively close and transportable by water or canals) but not in France (hung up with abundant wood, charcoal and water sources and coal mines disseminated throughout the countryside with costly or no transportation and a system of tariffs that benefited traditional industries) or initially in Germany (who had not discovered concentrated easily accessible known deposits of coal that led to the neglect of the possibilities of mineral fuel). Better processes upstream and downstream such as the working of the minerals

90% of the increase on the second half of the Century.

[167] That is, it is possible to move ahead in some areas while lagging in others.

[168] The substitution of coal for wood freed the nascent industry from the bondage of inelastic supplies.

and shaping them into products initially for processing wool, later cotton and eventually for transportation, power generation through coal provided the basis for the steam engine and later on the internal combustion engine. The increasing demand for manufactured products created an exponentialoid increase in the demand of energy hence coal and the steam engines.

The steam engines had a voracious appetite for iron, which called for further coal and power. Steam made possible the factory city, which used unheard of quantity of iron in the building and in machines hence more need for coal and iron mining and processing. The processing of the flow of manufactured commodities required great amounts of chemical substances. All of these products, iron, coal, textiles and chemicals depended on large scale movements of goods on land and on sea from the sources of the raw materials into the factories and out again to near and distant markets. The opportunity thus created and the possibilities of the new technology combined to produce the railroad and steamship, which added to the demand for iron and fuel while expanding the market for factory products and so on in ever-widening circles.

The process generated wealth for the owners and income for the laborers to satisfy their basic needs and additional wants; The cycle created more need for products and for a time became a self sustaining cycle with bumps and coughs until the next industrial revolution propelled it to another plane.

Education

Technical improvements were in turn driven by the 'rationality' that means could be focused to achieve specific ends. Education was stratified in working classes that emerged from the craft through the guild and then through particular learning processes for transferring knowledge called education. In 1850 technology was essentially empirical and on-the-job training was in most cases the most effective method of communicating skills. The flow of knowledge throughout the First Industrial Revolution is from tinkering to empirical observation to theoretical speculation to a pseudo scientific process to a scientific process.

There were also on-teaching academies, museums and most important perhaps, expositions (a kind of advertising before the age of penny paper and mass publicity). Expositions did much to stimulate technological emulation and diffuse knowledge. Education slowly supplanted an oral tradition with a more formal written tradition (and the advent of formal mathematics, geometry, and graphic model interpretations). Education, mostly of government backed, became more dependent on the notion of communicability of experience if it can be perceived, described, perhaps even measured, by any person with the requisite faculties and instruments in the same terms.

This communicability of experiences is the basis of scientific and technological advance because it made possible the transmission of knowledge separate from dreams, religious experiences and other transcendental impressions that leave a legacy of emotions, attitudes and values but do not add cognitive building blocks. A form education propelling the industrial revolution is the work ethic propagated by different sects, such as Protestantism, but this is a complex and embroiled question. What is important for this analysis is the significance of the Calvinistic ethic, whatever its source, as an extreme example of the application of rationality of life: The insistence of the value of time, the condemnation and abhorrence of pleasure and diversion which reinforced a Faustian ethic, the sense of mastery of nature and things. Mastery entailed an adaptation of 'means to ends'; and attention to 'means and ends' was a precondition to mastery.

Summary of the First Industrial Revolution (I-IR, ca. 1700 -1850)

Both the word-pictorial presentation and the summary are used to generate the CLA and the list of elements of influence.

Inventions were 'autonomous' according to Landes and were followed by rapid innovations and adaptation of new products, technologies, methods, organizations, processes to different disciplines. In particular regarding the issue of discipline and supervision:

> "Supervision and discipline were not entirely new. Certain kinds of work – large construction projects for example – had always required the direction and coordination of the efforts of many people; and well before the Industrial Revolution there were a number of large workshops or 'manufactories' in which traditional unmechanized labor operated under supervision. Yet disciplines under such circumstances were comparatively loose (there is no overseer so demanding as the steady click-clack of the machine) and such as it was, it affected only a small portion of the industrial population."

Technology was stimulated by the real need to create substitutes for overseas imports, although the size of the initial lump of investment was itself an obstacle for change. Up to some historical point, the Continental market was not developed, that is, it was so fragmented that for all practical purposes there was no market except for a few and mostly local staples. Some productions grew in scale but little in technique. Other industries, in certain countries like France and Germany preferred voluntary obsolescence by buying second hand machines and technologies.

Although there had been advances of commerce and industry in history that have been impressive, most of them have been 'more wealth', 'more goods', in prosperous cities such as in Medieval Italy and Flanders. In the absence of qualitative changes of improvements in productivity and value, there was no guarantee that mere quantitative gains would be consolidated and sustained. It was the Industrial Revolution that initiated a cumulative, self-sustaining advance in technology whose repercussions are felt even now. Within the Industrial Revolution, each innovation seems to have a life span of its own, comprising periods of tentative youth, vigorous maturity, and declining old age. As its technological possibilities are realized, its marginal yield diminishes and it gives way to newer, more advanced techniques. Thus the climb towards a kind of asymptote of textiles, iron and steel, heavy chemicals, steam engineering, railway transport began to slow towards the end of the nineteenth Century, so much so that some observers feared that the whole system was running out of steam.

Overall, the flow of the First IR is depicted in *Fig. F.2*.

Recapitulation of the Method of Analysis

Based on the stories of the First Industrial Revolution a Causal Loop Analysis is performed in *Fig. 4.9*. Causal Loop Analysis (CLA) as an interpretative tool frequently used by Soft Systems Analysis and Systems Dynamic Modeling (Anderson and Johnson, 1997; Spector et al. 2001). Causal Loop Analysis is an iterative method for driving out of a story the 'variables', 'link's and 'loops' and the substantive 'assumptions' and 'data' that can be used to back the story line. Its main usefulness is when the principal source is a story or narrative (such as the IR story, the high-rise building story, the Air Condition story, and the Elevator story). This interpretative method (Shelby 2001) allows a graphical depiction of the Variables, the Links and the Loops contained in the story with the hopes to be able to reach back on the Assumptions made and eventually capture the data (quantitative) supporting the story, see *Fig. 1.3*. (Chapter 1, Methodology).

Economic Development → Balance of trade → Wealth → Tax Revenue → Power → Stable Employment → Public Order.

Fig. F.2 Flow of the First IR

Beginning with the story or event (CLA is based on the understanding the world as a series of events), we proceed through a process of identifying the variables, establishing links between variables and creating loops based on the links.

The purpose of CLA is to find if there is a systemic structure driving the results to find the trends, directions, magnitudes (increasing or decreasing) and any other metrics that can substantiate the findings. A variable should be measurable (that is a trend chart of the variable desired) and describe the things that actually change. Variables are those things in the story that change that increase or decrease over time. The CLA methodology is based in the discovery of increasing levels of complexity from events (the world as a series of describable events); patterns (leverage begins with pattern recognition, that is: this has happened before – which is a basic insight not always readily recognizable and obvious); study of the systemic structure (documentation of the systemic dynamics that maintain the CLA). Once a pattern has been identified and described, it is possible to document the systemic dynamics that maintain it. The level of systemic structures marks the boundary between what can be easily observed in the objective world (events and patterns) and what must be assessed, often laboriously, from the data (mental models and visions). Systemic Dynamics are abstractions, but they stay close to the data. For example in today's world there can be a bias towards thinking that government has a link towards resources such as technology, but during the First IR, as observed from the narrative of experts, there was no such link.

Thus each one of the loops and associations track closely the information from the narrative.

The weak link with historical events is that the narrative (i.e. from Landes and others) is taken as a surrogate of real events. From CLA a Soft Systems Methodology can be applied to obtain the 'Root Definition' of the subject (see *Fig. 1.4)* and the Flow of variables (see *Fig. F.3*

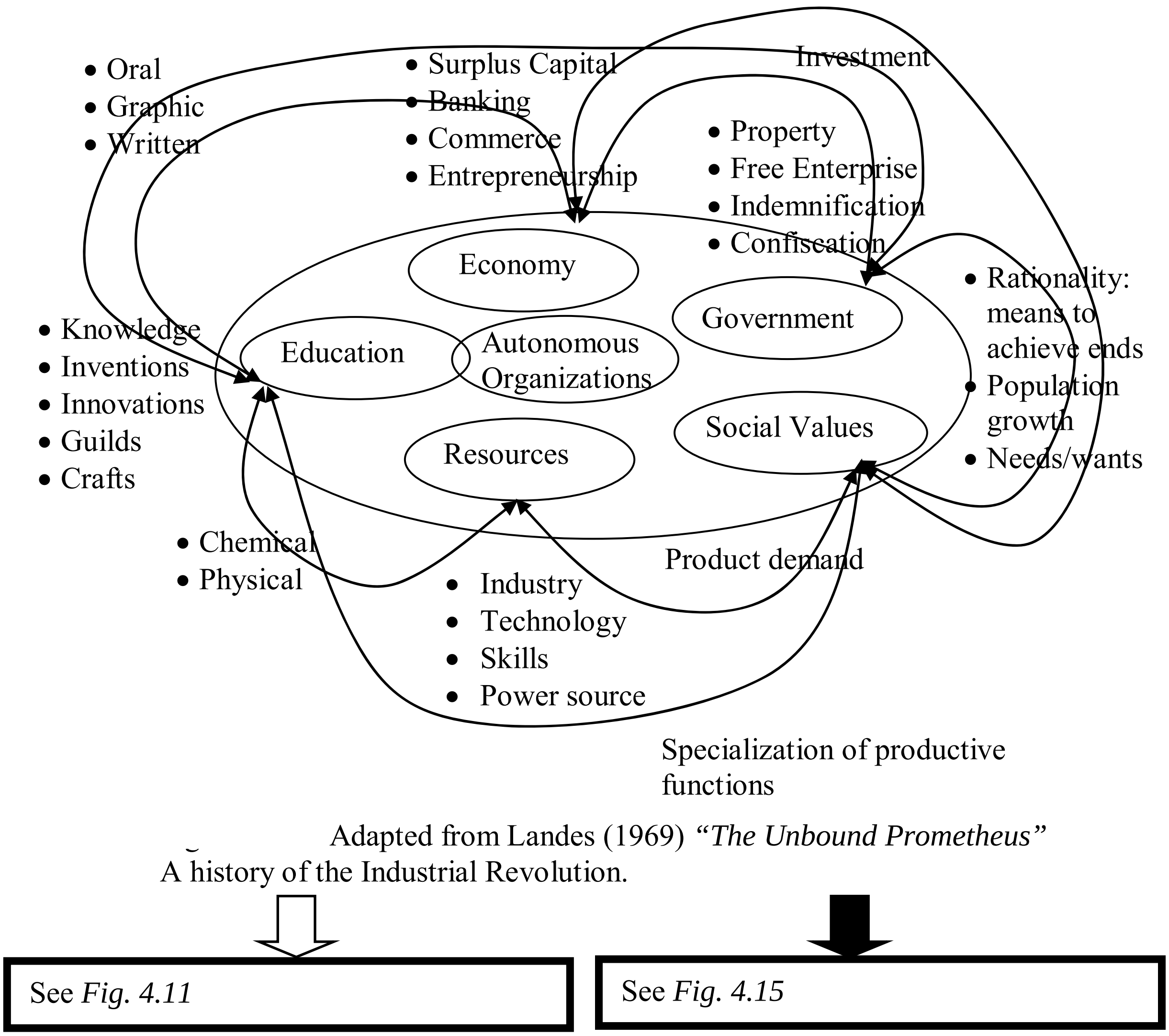

Fig. F.3 CLA of the Industrial Revolution to deduce Elements of Industrial Change

APPENDIX G

THE SECOND INDUSTRIAL REVOLUTION (II-IR, 1850 – 1940)

The birth of electrical power and motors; organic chemistry and synthetics; the internal-combustion engine and automotive devices; precision manufacture and assembly-line production form a cluster of innovations that have earned the name of the 2-IR (Landes 2003).

Demographics

In the beginning the 2-IR ran out of national and regional "customers"; its productivity surpassed the localized population curve. A new international search for customers ensued. China was a favorite subject for suppositions with a population of well over 300 millions! "If the Chinese or Indian levels of cotton (wool, iron, etc…) consumption per capita could be raised to the British levels…[169]"

Climate Change (continued)

Due in part to continued favorable climatic conditions, the advent of chemical fertilizers and pesticides, weed killers, food prices in the Continent dropped after 1875 as a result of massive flows of grain from the Great Plains and steppes of North America and South Russia, ever larger imports of meat from Argentina and of oils and fruit from tropical and semi-tropical areas. Improvements in transportation and cultivation with the extensive use of fertilizer ushered what is termed as the "agricultural revolution" (1750-1900). Starting by the plow pulled by animals that made agricultural production vastly more efficient than before, permitting far more land to be farmed by fewer people. The addition of fertilizers yielded even greater food surplus and it also freed far more people for other types of work, the beginning of a greater division of labor (http://www/missouri.edu accessed 6/9/06).

Social attitudes

A body of consumers was created that went beyond needs into wants helped by fixed prices, catalogue orders, effective display, periodic sales, and advertising by the cultivation of fashions, the establishment of trademarks and brand names. World expositions continued to serve as the showcase for technological and industrial prowess.

Landes 2003 provides the following description of prevailing social attitudes: "Whereas the British insisted that everyone in the world ought to speak and read English and count in pounds, shillings and pence and was reluctant to abandon the individuality of tradition in a conservativism in the face of new techniques, the German entrepreneur worked long hours, expected the followers to do likewise, watched every *pfennig*, knew every detail of his operations, had no antiquated veneration of quality, was skilled in meretricious presentation, accommodating on the terms of sale, energetic in prospecting for new customers and tenacious in serving them". The importance of this picture in words is the social vector of one society that begins changing sense and direction due to norms and cultural biases when contrasted with the social vector of another society.

Entrepreneurship

Entrepreneurship turned to first the substitution of machines and inanimate power for human skills and strength; second the conversion of the operative into an automaton to match and keep pace with his equipment; and in the 3-IR the replacement of man by machines[170] that think as well as do.

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[169] As noted in Chapter Two of this dissertation this dream is materializing in the Twenty First Century, for China, and with India following close, affecting the global economy rather than just one or several national economies.
[170] Apparently, it is easier to make machines like man than to turn man into a machine.

Organization

Once labor got established in the older assembly industry (like it had in building construction) the engineering trades, strongly organized, craft oriented and fearful of technological unemployment, fought all changes in conditions of work (Shadwell, 1922). Technology and social patterns reinforced each other. In the early decades of the Industrial Revolution, when rapid changing techniques offered large returns on investment and efficiency, and mechanization in particular yielded spectacular gains in productivity over hand work, labor efficiencies lost in relative importance. Once the plants were set, Eric Hobsbawm (Landes 2003) citing *the Carding and Spinning Master's assistant* of 1832, warned against rearranging machine installations, even if inefficient on the grounds that cost would probably exceed savings.

Fixed wages were preferred over piece wages and reliance set on foreman and master workmen's hard driving to get the value for the money. This accounts for the ability of labor to maintain output in the short run, but also for the almost universal failure of technological innovations to yield the productivity gains they theoretically made possible. With time wages the work could and did increase imperceptibly as productivity rose.

Frederick W. Taylor (1933) study led maximization of the product of labor of Midvale Steel Works in Pennsylvania in the early 1880's. His method, dubbed Taylorism, is comprised of (1) careful observation, analysis and timing of worker's movements; (2) precise measurements of labor costs of each operation; and (3) the establishment of norms based on these calculations that led to the discovery of both weaknesses and possibilities of improvement. As a result he discovered high-speed steel: or that he worked out correct tensions and speeds for power belting and an efficient procedure for the maintenance of what had always been the responsibility of no one in particular (like oiling and grinding). This led to the optimum pace of work and setting the standards of efficiency for aspect of production (Copley, 1923).

Accounting became the area of most rapid advance; however, it was easier to improve the flow and quality of intelligence than to act upon it. On the other hand the system allowed calculating the costs of complicated jobs in advance. Without prediction, there could be no competitive bidding as we know it. Accounting (nowadays estimating), organizing and planning (modern management) were beginning, but only beginning, to dominate the shop.

Organization was required for precision manufacture with interchangeable parts. Several minor innovations and inventions were essential: (1) Improved lubrication[171] and (2) substitution of steel for wrought iron (greater precision in the manufacture of moving parts). Manufacture organization became integrated vertically in order to free itself from the exactions of collusive suppliers or customers, opening the way to new economy of scale (increase of personnel, physical output, increase in productivity, thus reducing the gap between the 'best possible' and the 'best practical'. This legacy can be analyzed from material extraction, transformation, organization, flow of the work (logistics of production), transportation etc…

The gap is the discrepancy between anticipation and event. Industry's peculiarity is that of fixed obsolescence that is magnified by scale. Any labor saving innovation through scale has another side of the coin – the multiplier effect on the costs of inefficiency. The greater the outlay on plant and equipment, the less one can afford bottlenecks, sloppiness, slack or even worse inefficiency that is infectious and tends to contaminate everything around.

[171] Including forced lubrication which made possible quiet running at high speeds with little wear and without the risk of seizing, along with ball bearings for the even distribution of loads and reducing the distortion produced by wear to tolerable proportions (recuperating as much as 90% of the power losses in shaft transmission).

The word pictorial behind this narrative indicates the gap in efficiency that will later be closed through the principles of ever increasing scientific managerial interventions with the aid of technologies (mechanizations and automation).

Technology

New materials, the age of steel was ushered in by technicians that went beyond what Landes (2003) calls 'tinkering[172]' and into science. The salient advantages of steel were: great strength in proportion to weight and volume; plasticity; and hardness. As a result of the intimate connection between ferrous metals and machines, the consumption of iron per capita has always been one of the most accurate measures of industrialization. Bessemer, Siemens-Martin and Thomas steel inventions are notable. However even these inventions propitiated an Indian Summer of growth and achievement in obsolescence derived from several factors: (1) a creative technological response to the challenge of the new competitor; (2) a compression of cost and elimination of waste in the struggle for survival; (3) opportunities derived from the demand crated by the more efficient technique.

The British 'tinkered and improvised' and the irregularity of their product merely confirmed the doubts of consumers, which in turn discouraged experiment and investment. While the British motto during this epoch was "make wealth", the German motto was "make it better" through purposeful research. "Technical virtuosity, aggressive enterprise, leap to hegemony, almost monopoly had no parallel and became Imperial Germany greater industrial achievement.

[172] Tinkering is used for lack of a better term that encompasses the following concepts: Applied manipulation of formulas, mixes, machinery in what some term 'innocent empiricism' in contrast with a theoretical based, academic promulgated scientific approach to technological findings and applications in a scientific, capital intensive, mechanized technological efficient focused invention and innovations. Tinkering could take place with knowledge levels 1, 2, and 3 but not level 4 in the below mentioned Education section.

Inventions / Innovations

German open hearth was bigger, consumed less ore, had continuous conveyors, traveling cranes, tiltable furnaces and suspended railways powered by the new found electricity. In 1883 the Germans had 34 standard shapes, the British 122[173].

New sources of energy and power are divided in three parts: (1) the primary sources of energy power: gas, oil[174]; chemical substances that liberate heat or electrical current in reaction; (2) Motors[175] and the conversion of energy into movement[176]; (3) The electrical distribution of energy[177] giving transmissibility and flexibility to this source of energy. Electrical demand had to be heterogeneous. The house utility demand (incandescent lamps, and radio - of little consumption - refrigerators, electric heating, washing machine, etc… with higher consumption load) was quickly supplemented with heavy industry demand such as in the iron industry, electrical traction devices (electrical railway) tramways and subways, heavy electro-chemistry such as the Hall-Héroult method of aluminum manufacture (1886) and Castner's sodium, sodium Cyanide, and caustic soda processes (1886 and 1894) and motor power (both fixed and mobile) making power available anywhere both outside and inside the plant.

New uses (applications) and cheaper power promoted capital formation. Technological improvements have tended to increase the ratio of work output to energy input and therefore to diminish capital requirements at a given level of power consumption. In effect every

[173] The United States had 33 standard shapes of angles and channel sections (Burn, *Economic History* as cited by Landes, 2003).
[174] Old forms of energy: falling water; burning carbon (in the form of wood, coal), the sun.
[175] The internal combustion motor with the principle of a channeled explosion.
[176] Specially the technological breakthrough of the steam turbines allowing rpm's from 1,200 to 18,000 and much higher allowing rotary motion and large-scale electrical power industry.
[177] Electricity is not a source but a form energy. Electrical dynamos and similar generators are essentially converters, turning water, steam or other primary power into current, which can be stored in batteries, used directly for illumination, heat or communication or transformed into motion by means of motors. Transmissibility through space without serious loss allows the consumer to pay for what he uses. Before electricity the transmission of

improvement in the efficiency of the production or utilization of energy has encouraged the substitution of fixed for working capital. In a sense, the story of power is the story of industrialization. There was no activity that could not be mechanized and powered. This was the consummation of the 2-IR with the underlying stability of the resource base of industrial power: the continued growth of power consumption.

Regulatory framework

Some countries like Germany found it difficult to meet the needs of growing domestic industries and discouraged the export of capital on the explicit grounds that domestic needs were urgent and should receive priority. French banks, on the other hand, were reluctant to entrust their funds to domestic industry, as undeserving of confidence, but thought of German banks as a good risk. The 2-IR required a heavy investment in social capital: in particular roads, bridges, ports, buildings, transportation systems, schools for general and technical education.

The latecomer had an advantage over the established. Micro-economic costs fell most heavily on the early industrialized; the other, essentially macro-economic[178], fell most heavily on the follower country. The early ones became outdated technology with unsuitable infrastructure. The follower had to invest heavily on infrastructure to catch up but once there had the advantage of education, newer infrastructure and the option for the latest technologies[179].

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energy was limited to 500 feet by fluid (water or oil) or gasses (air) under pressure in rigid or flexible hoses in direct force (rather than motion) application such as lifts, pumps, presses, punches and brakes.

[178] Macro-economic change is rarely abrupt, simply because the system works imperfectly (Landes, 2003).

[179] According to Landes (2003), where the gap between leader and follower is not too large to begin with, that is, where it does not give rise to self-reinforcing poverty, the advantage lies with the latecomer because the effort of catching up calls for entrepreneurial and institutional responses that, once established, constitute power stimuli to continued growth. This lesson is especially applicable to the current newcomers to the global market: China and India.

Economy

Mass leisure became a powerful market force, for the first time in European history, and the service sector grew apace: banking, insurance, professionals, recreation and travel among others.

German banks stayed with their creations, held on to some of their stock, kept an eye on their performance, and encouraged their growth as lucrative clients. The decline of the lucrative railway construction and nationalization saw German Industry integrating along vertical and horizontal lines, with a more thorough utilization of resources and a more effective combination of the factors of production (Jeidels, 1905). The German experience can be generalized, although with exceptions, in two maxims: First, it is not money that counts but what one does with it, and secondly, that capital flows to opportunity, that if there are borrowers who know what to do with it and seek it, there will be lenders to meet their needs.

British manufacturer admiration and preference for experience, empiricist tinkering as against bookish experiment was inclined to be suspicious of novelty. 'Generally speaking', records Minchinton (1954), 'when anything new is introduced into any work, if it is not right away a success out it goes'; the response to something new as to ask 'if any other fool had tried it yet'.

Education

Germany's belated start, the rapid rise based on technological excellence and rational organization, the concentration of production and the strong position on the world market is in large part attributed to the education process. By education we mean the imparting of four kinds of knowledge, each with its own contribution to make to economic performance: (1) the ability to read[180], write (draw) and calculate; (2) the working skills of the craftsman and mechanic; (3) the engineer's combination of scientific principle and applied training; and (4) high-level scientific knowledge, theoretical and applied.

The British Education act of 1870 according to H. G. Wells (Lowndes, 1937) 'was not an Act for common universal education, it was an Act to educate the lower classes for employment on lower class lines, and with specially trained, inferior teachers who had no university quality.' Robert Merton cites that it was not even to instruct but rather to discipline a growing mass of disaffected proletarians and integrate them into British society.

Compulsory elementary education in parts of Germany dates back to Frederick the Great's issue of his General Landschulreglement in 1763 that although poor created schooling as the cornerstone of the social edifice. The School systems of Germany by the early eighteenth Century were famed throughout Europe. The state not only had an obligation to instruct its citizenry, but found its advantage therein. The very antiquity of the system obviated the emphasis on de-barbarization that marked the British system and therefore a concentration on instruction. And lastly, schooling tended to last longer in such a way that some selection of talent occurred.

The link between formal vocational, technical and scientific education and industrial progress appears to be more direct and evident (Kay, 1850). The greater complexity and precision of manufacturing equipment and the closer control of quality, in conjunction with the growing cost of inefficiency and pressure of competency (especially on the upper levels of the productive hierarchy and designers). Also, the high cost of equipment made on-the-job training increasingly more expensive and helped break down an apprenticeship system. Lastly, the

[180] Large share of the work of industry can be performed by illiterates, even foreigners that do not speak the

higher level of scientific content of technology required employees, (supervisors and workers) to familiarize themselves with new concepts, scientific novelty and the economic significance of productivity.

British attitude at that time, according to Huxley (1884) "were convinced the whole thing was a fraud, the effective technical education was impossible, scientific instruction unnecessary, attested by the success of the uneducated entrepreneur, a barber like Arkwright, a clergy-man like Cartwright, and instrument-maker like Watt, a professional amateur inventor like Bessemer and others. A mystique of practical experience in opposition to academia was developed. In contrast, the kings and princes of central Europe vied with one another in founding schools and research institutions and collected savants as their predecessors collected musicians and composers or other courts artists, musicians and sculptors. The German system had institutionalized innovation; change was built in through education.

On the supply side, the establishment (as early as 1790's, that is during the First IR) of institutions of engineering instruction, made possible to transmit certain elements of contemporary science. On the demand side, newer fields of industrial activity such as organic chemistry and electrical engineering tended to diminish reliance on the traditional combination of empiricism and common sense and impose a more scientific approach. The task of invention was getting more complex, the matter of invention more recondite. Applied science was a more efficient key to the unknown, hence more prolific of innovations such as non ferrous metallurgy as the Hall-Héroult aluminum and Mond nickel process. In summary, industry could now order desiderata from the laboratory as a client a shipment. Technology was no longer a relatively

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language! Literacy provides the foundation for more advanced work and facilitate and stimulate mobility.

autonomous determinant; instead it had become another input, with a relatively elastic supply curve.

Summary of the Second Industrial Revolution (II-IR, 1850 -1940)

Both the word-pictorial presentation and the summary are used to generate the CLA and the list of elements of influence.

The actors across the nations during this period perceived the market as saturated of the inventions and innovations developed during the 1-IR. However the birth of electrical power and motors, organic chemistry and synthetics, the internal combustion engine and automotive devices requiring precision manufacturing and the development of assembly line production formed a cluster of innovations. Population and personal wealth grew firming up the class of consumers first to satisfy needs and an increasing demand to satisfy wants.

Inefficient machinery was retained, as even the re-arranging of equipment, in order to achieve greater efficiency was deemed not cost effective creating an atmosphere of achievements in obsolescence. 1-IR double digit productivity gains were not as readily achieved although Taylorism led the way of a new way of looking at organization and production from an accounting managerial perspective. Cost calculations (estimation) and planning began making inroads into the industry's systemic organization.

Inventions and their subject matter (organic chemistry and electricity as a new source of energy and power) became more recondite and complex (precision manufacture vs. irregular manufacture with standard vs. non-interchangeable parts). 'Innocent empiricism' became 'focused empiricism' reliant on education, academics, theory and scientific methods. The German latecomer model of catching up by 'making it better' through purposeful research, and social attitudes backed by increased governmental economic and educational interventions led to the breakthroughs in technology (high level scientific knowledge, applied theories, institutionalized innovation through education) that made previous technologies obsolete.

Building Construction of houses and buildings with electricity was a contributor to the momentum of the 2-IR, promoting capital formation through increased power consumption. By the end of the 2-IR housing electrical demand, especially heating was greater than that of industry throughout Europe and America. Immobiles, also known as fixed assets, became part of the large initial outlay of capital, along with equipment at the front end. Operations, maintenance, technological upgrading, labor etc became larger in the back end. Long term and short term strategies were nascent in the industry at this time.

Heavy and light industries matured and received an incremental push by linking with other nascent industries (chemistry, electricity) and entrepreneurial practices (organization, accounting, and vertical integration).

The Second Industrial Revolution is considered to include the cluster of spectacular advances in chemical and electrical science, steel, oil derived from fossil fuels as the primary source of energy and the internal combustion engine as a new mobile source of transportation power.

APPENDIX H

THE THIRD INDUSTRIAL REVOLUTION (III-IR, 1940 - 1990)

One of the strangest paradoxes of modern history is that on the one hand, Britain, a liberal society standing out from all others in the eighteenth Century for equality and mobility of status, should have lost some of these during the very period of its progressive political democratization; while on the other, a far more authoritarian society, such as Germany, characterized in its pre-industrial period by a clearly defined, fairly rigid hierarchy of rank, should have developed a more open structure, without corresponding political change[181]. British could build its industry from the ground up, the Germans found it necessary from the start to create institutions to mobilize capital and channel it to a productive system taking its departure on an advanced level of technique and organization provided by institutionalized education.

The 3-IR had within itself a steady flow of small improvements which cumulatively constituted a technological revolution and the development of inventions for commercialization that appeared during the earlier phase of the IR.

Demographics

Lewis (1949) observes that trade slowed down because population growth had slowed down. The major factor was the war: Europe had some 22 million fewer people in 1920 than it should have had, and if Russia is added the deficit becomes 48 million, with a decline in birth rates that will become more important in the 1930's.

The end of WWII saw further population attrition. If the numbers had continued to grow at the rate of 1920-1940 (a fairly low rate for Europe at that) population would have stood at 806 million in 1950. Instead it stood at 751 million, a deficit of 55 million of which 15 million in

Europe and 40 million in the USSR after some five years of recuperation. This era saw the accumulation of unsatisfied wants first thwarted by the depression, then by years of conflict and destruction, followed by an economic inflationary cycle (King and Timmins 2001).

Climate Change (continued)

There is no substantial historical record of how climate change in this period affected the industry, probably because the magnitude of the events of WWI and WWII overshadow and embed any significant change.

Social attitudes

The first recourse in a growth economy is the unemployed capacity as may have existed before the increase in demand. With a large number of unemployed, capital tended towards the tried and true techniques with the overall effect of widening rather than deepening industrial production. That is, using existing outmoded means of production and absorbing cheap unemployment, rather than incorporating the latest manufacturing technologies, techniques of production and organization in a drive towards achieving increased efficiencies.

Products for the masses, rather than commodities for the wealthy drove the economy during this period, for example: The radio, considered what is called a counter-income or counter-status luxury, is a product whose utility varies inversely with income and which therefore is taken up by the poor faster than by the rich. The television is an even better example and to a lesser extent the automobile, although this counter-income luxury feature would come up in the latter part of the 3-IR.

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[181] There appears to be some parallel with the current industrial and economic growth and politics in China.

Entrepreneurship

Even when the British entrepreneur was rational, his calculations were distorted by the shortness of his time horizon, and his estimates were on the conservative side, in contrast with the rationality of the Germans. Theirs was a different kind of arithmetic, which maximized, not returns, but technical efficiency. The new was desirable not because it paid, but because it worked better. There was a right and a wrong way of doing things and the right was the scientific, mechanized, capital intensive way. German entrepreneur had a longer time-horizon and included in his estimates exogenous variables of technological change that his British competitors held constant.

Market competition, according to recent economists, is never as efficient as it is in theory; that is, it is never strong enough to compel all enterprises to purchase and use all inputs efficiently; and therefore, that there is between actual and optimum practice a substantial gap that can and will contract under additional pressure. The gap between perceived 'best possible' and 'best practical' practices at a given time is the rationale behind 'changes' of the Industrial Revolution. Unfortunately, we do not have the data and historical information to articulate 'best possible' and 'best practical' practices at any given time.

The potential gains here, notes Harvey Leibenstein, are of an entirely different order from those imputed to improvements in the allocation of resources. Instead of fractions of 1 per cent, we are talking on the level of the individual enterprise- of labor and capital savings of between 10 and 50 per cent, sometimes much more. Leibenstein argues that it is precisely these gains achieved by this kind of response that constitute a good part of the so-called 'residual' – that part of the growth of national product that cannot be accounted for by inputs of land, labor and capital. This residual amounts to some 50 to 80 per cent of the recorded growth of advanced industrial nations.

Significant changes are almost invariably the resultant of mutually sustaining conjuncture of factors, so that most variables are at once both cause and effect, independent and dependent, yet they constitute the autonomous first cause or prime movers. These encompass a whole array of recalcitrant qualitative factors, ranging from educational, organizational, technological, scientific sources of new knowledge, through the translation of this knowledge into economic applications, to the quality of the actors involved (demographics, social, 'human capital') and the organizational arrangements and entrepreneurial decisions that govern their actions.

Organization

German organization (the Four Year Plan) under the Third Reich had four aims: (1) increased self-sufficiency; (2) the relocation of strategic industries away from the frontiers (particular the development of a new centre of steel and chemical manufacture in central Germany); (3) the expansion of the capacity of strategic branches; and (4) the rationalization of industrial organization and technique.

Most producers found it easier and more profitable to put unused capacity back into production rather than to innovate. In 1943, French metallurgical plant was in a state of profound obsolescence. This era was more concerned with the questions of stability and organization rather than growing, and to the extent that they turned their attention to growth, especially by accountants, they gave little thought to the implications of continued technological change. On the other hand, American economic performance (even in the midst of unemployment and a prolonged depression) continued based on what we now call Research and

Development[182] (R & D). Articles in Fortune 1939, appeared to the extent that although 'population growth is slowing down' to keep the rate of investment, some offset would have to be found on the side of invention. Hensen argued on the other hand that advancements in industrial production would prove to be capital and labor saving and thereby reduce the demand for capital as well as for labor (King and Timmins 2001).

Technology

Technological innovations appear most distinctly under the Third Reich who anticipating the possibility of war was determined to avoid the mistakes of WWI. In all domains, the state bent its efforts to promote national self-sufficiency. Domestic resources such as iron ore were exploited beyond the limits of commercial profitability. Substantial portion of national research went towards the discovery or invention of substitutes for imports like petroleum, rubber and cotton, the processing of cellulose from wood, straw and other organic materials, new uses for light metals like aluminum, invention of new allows, innovating the substitution of glass and plastics for steel, the processing of low-grade ores, continuous strip mills. Businesses were compelled to invest in costly and risky technologies and forced manufacturers to choose plentiful as against scarce, domestic as against foreign, artificial as against natural raw materials even at the expense of quality. Assembly line use grew and products were standardized.

Change was built into the system, and the engineers and technicians kept working so long as their employees paid them and furnished the means. The gain in overall efficiencies in energy conversion was part of a long trend going back as far as our statistics permits us to go. The trend was a result of improvements in the techniques used to produce both comfort heat (the shift from

[182] Gilfillan (1962) calculated indexes of 'inventive inputs' for the USA from 1880 – 1955, including among other things the number of members of scientific societies, of graduates from engineering schools, and of professional personnel in organized research) with a 226-fold increase.

open fireplaces to stoves, and eventually to central heating) and work (shift from water wheels to turbines, savings in steam engine fuel consumption, introduction of the steam turbine) but domestic heat consumption has always been far greater than that of engines and motors of industry. Total electrical output in Britain in 1926 was of 12.7 Billion kWh and 35.8 Billion kWh in 1939 (Landes, 2003).

The French householder took a long time to get accustomed to the desirability, even the necessity, of domestic appliances, using electricity mainly for lighting and radio and often but not always an iron. The more costly appliances – refrigerators, stoves, water heaters, vacuum cleaners, and the like – were viewed as bourgeois luxuries and even the bourgeoisie seems to have adopted them with reluctance: 'refrigerators alter the taste of food, the electric oven is not suitable for making delicate pastry, and the gas stove is no substitute for cooking over wood…' Actually, the refrigerator in a northern climate such as in Paris, even nowadays, is not necessary if one shops daily or even several times a day. Most French houses were wired with entry services of two or three amperes for modest apartments even after WWII and perhaps ten amperes for a bourgeois flat in Paris (Lejay, 1933).

The United States of America (USA) introduced, because of the automobile and later on the airplane, precision manufacture, interchangeable parts, and the assembly line. These features brought the automobile within reach of the workers who made it. From 1923 to 1938 the four leading European carmakers (U.K., Germany, France and Italy) produced 10 million motor vehicles against 37 million for the USA. The motor industry was beginning to play at this point in time a role analogous to that of the railroad in the mid-nineteenth Century: it was a huge consumer of semi-finished and finished intermediate products (sheet steel, timber, glass, and paint) and components (tires, lamps, generators, etc.); it required a small army of mechanics and service men to keep it going; and it gave a powerful impetus to investments in social overhead capital (roads, bridges, tunnels). At the same time it posed new technical problems in metallurgy, organic chemicals and electrical engineering, eliciting solutions that had important consequences for other industries as well, yielding a rich harvest of forward and backward linkages.

The automobile affected building construction with the added necessity of the carport, then the garage, parking decks, transportation that allowed a secondary residence and the emergence of suburbia associated with urban centers. The combustion engine affected building construction in far many other ways, especially material transportation and heavy equipment. Electricity brought the light industry methods of production and assembly to the job-site.

Inventions / Innovations

The interwar years saw no major departure from the technologies of the prewar generation. These decades saw the working-out of the discoveries of the prewar generation finding technological and commercial fruition. The pre-war division of the old and new branches of the industry remained and the composition of the groups is unchanged. On the one hand we have the newer industries of electrical power, electrical manufacture, chemicals, the automobile[183] and a flying tricycle (later known as the airplane); on the other the older industries of manufacture of textiles from natural fibers, iron and steel, machine tools, shipbuilding, railway transport. The former show rates of growth far above average, the older branch grows slowly, stands still, or even declines. Technology is not ossified, but advances as do occur offer relatively small gains

[183] The automobile had two advantages that more than compensated for the high cost and inconvenience (lack of repair facilities, few garages for refilling, few spare parts supplies, frequent flat tires etc…): the thrill of speed and freedom of movement.

and given the state of the market find slow application (Kuznets, 1929) even with the application of technologies derived from the new industries to the old.

Germany's production of synthetic gasoline with the hydrogenation of lignite, synthetic oil by the Fisher-Trapsch technique, and diesel oil by the low-temperature carbonation process were undertaken through the state control and threat of raw material supply, electric power, labor and credit, and the ultimate possibility of recourse to physical or even lethal force.

The end of WWI saw the possibilities of the airplane, motor vehicles, refrigerators, washing machines, electric irons, space heaters, the telephone and radio. The end of WWII saw the possibilities of a myriad of inventions and innovations that are still with us today in some form or another such as rayon fabrics, nylon. Almost every advance of importance in this period has been credited to two or more people: the alternator to Fessenden, Ernst Alexanderson (General Electric), and Rudolph Goldschmidt Allgemeine Elektrizitäts-Gesellschaft); the triode valve as amplifier to von Lieben (Germany) and Edwin Armstrong (USA); the feedback circuit to Armstrong, Meissner (Telefunken), De Forest, Irvin Langmuir (General Electric), and C. S. Franklin and H. J. Round (English Marconi); the valve as generator of high-frequency oscillations to Meissner (Germany), Armstrong, Franklin and Round. This new breed of inventors and innovators was far better trained in science than their predecessors of the eighteenth and nineteenth centuries; electronics, like chemistry, was too esoteric to admit innocent empiricism.

The evidence for the speed of technological change usually takes the form of comparison of the development time of yesterday's inventions and innovations with today's. The steam machine took a Century from paper sketches to the high-pressure engines of Trevithick and Evans; nuclear power went in less than a generation from theoretical equations to commercial stations (Landes 2003; McHale 1972; García Bacca 1989 provide multiple other samples of this hypothesis).

France, the UK and Germany were all affected in different ways than the USA that became a source of finance, material and human power in the European theater as well as in the Pacific theater of war. Lynn's (1966) study for the United States Commission on Technology, Automation and Economic Progress on the rate of maturation of twenty major American innovations of the period 1880-1925 shows an average span of 37 years from conception to commercialization during the period 1885-1919; 24 years during the post WWI era; and 14 years since WWII. Lynn shows that by far the greater part of these gains seems to have occurred in the cognitive phase, that is, in the interval between basic discovery and the start of commercial development. Moreover, in so far as the technological advances of the postwar years rest on a scientific base, it is a chemical and electrical base that goes back a Century or more.

Regulatory framework

Many of the aspects of the postwar period are manifest before 1914: the closure of markets against outside competition, the trend towards combinations in restraint of trade, the intervention of the state in matters once reserved to private enterprise or left to the free play of the market. The so called McKenna import duty in 1915 Britain was a fundamental shift in the world's largest free market. Russia withdrew from the international market along with Austria-Hungary.

Most nations put up barriers to competitive imports in an effort to soften the impact of diminished home demand. These restrictions on imports were applied to agricultural as well as industrial products. Their balance of payments, at best deficient, worsened considerably. Trade therefore, offered no exit to the sick and sulking economies of Western Europe. The alternative was an increase in home investment – whether endogenous, that is, growing out of the natural performance of the economic system; or exogenous, in the sense of being promoted by the state or other 'outside' agency; or both.

The USA post war contribution was massive through the Marshall Plan as well as other UN interventions towards reconstruction that is treated in greater detail under Economy. Britain's endogenous economic recovery was made possible by two forces: housing and the new industries. Housing boom of almost three million dwelling units was admittedly due in part to cheap financing (Richardson, 1967). Housing is not a mere shell created in the building process through materials and labor, but calls for electrical, plumbing fixtures, domestic appliances, furnishings and thus affecting utilities, specially electrical power generation and transmission. The location of these houses and commercial buildings promoted public and private transportation, which allowed the construction to take place in less expensive land.

British cartel promoted protective tariffs and the prescriptive use of British steel for national or municipal projects, including shipbuilding subsidized by the state with the provision that codes discriminated against the use of Thomas steel (basic Bessemer), which was the strongest product of Continental work. British lack of concentration and vertical integration left many large facilities operating at less than capacity and thus inefficient on the grounds of lost time, idle plant and idle capital. This in turn allowed the survival of the small units with them, older methods of manufacture. At the end of 1930 the steel industry was operating at 30% capacity.

Germany economic recovery and that of other European countries was exogenous in the abandonment of the notion that state intervention and control was limited to emergency intrusions into what should be a self-governing mechanism. The hand of the state became indispensable in good times as well as bad. Crisis have always entailed unrest, and no government can afford to stand idly and allow the hardships of its subjects or citizens to provoke them to insurrection, besides, depressions are costly to the state who perceives a vested interest in direct intervention[184]. In these countries, the economy, like any other aspect of national life, was looked upon to serve the state, rather than the state to serve the economy and the people. Political radicalization of the economy –the enhancement of German power - under Hitler is beyond the scope of this study.

France had a long mercantilist tradition and was never comfortable with the doctrines of *laissez-faire* as gospel. French entrepreneurs were accustomed to tariff protection, subsidies, and preferential tax treatment for selected branches of activity. The government had always been more highly centralized, organized and active than the British especially in the branches of banking, transport, electricity, manufacturing and infrastructure construction.

Economy

The collapse of pre-war monetary order affected a revolutionary change. All wars are inflationary, if only because so much is spent for unproductive or worse yet, destructive goods and services. The result, after the wars is a massive inflation due to pent up emergency ceilings, market quotas, rationing and the rest of the apparatus of economic compression. Once WWI was over and these restrictions were removed, the lid was off and prices shot up. Austria prices rose to 14,000 times pre-war; Hungary 23,000 times; Poland 2,500,000 times, Russia 4,000 times and Germany one trillion times. France borrowed 20 billion (mostly from the USA), the British £1,027 million from the USA (Landes 2003). Even with the postponement and eventual

[184] Previous state intervention is recorded in railway construction and operations not only because this was a task that in most countries was beyond the resources of private enterprise, but also because no branch of the economy was so clearly linked to the effective exercise of political authority and military power.

repudiation of war debts, most of the nations found the pegging of currency to gold as obsolete and some abandoned the standards, in most instances too late.

France had large gold reserves but assumed a unilateral stance of non-cooperation with her former allies, conditioning her economic good will on the political complaisance of those who sought help. At the same time she was even less tender with her former enemies, combating in particular Germany's efforts to improve her commercial situation which in turn affected French economic and political interests adversely. German banks collapsed. France, Switzerland, Holland, Belgium, Italy and Poland formed a gold block to settle balances among them in gold, but would not export gold outside the block. France became an expensive country in a cheap world in 1933.

In short American common stocks proved more attractive than national stocks but the trading was on speculation and when American banks began calling their European loans, the global economic depression of the late 1920's uncorked. By 1932 unemployment in Europe reached 15 million persons. The most striking aspect of this deceleration is its abruptness.

Monetary instability, new barriers to trade, and increased governmental intervention constituted together the major change in the economic environment during this period.

In Britain a process that might be called mummification was particularly marked, where the obsolescent enterprises were long nourished by financial resources accumulated in more prosperous years. The pre-war expansion propelling the II-IR was the result of: (1) a growth in ferrous metal with the supplanting wooden vessels by first iron and then steel; the railroad likewise supplanted iron rails with steel rails and a large increase in power plants; (2) The steel branch benefited from the changing pattern of demand; steel supplanting iron; (3) the technological creativity of the industry expressed in the Bessemer converter, the Siemens-Martin open hearth, the Thomas-Gilchrist process, the electric furnace; continuous strip mills at the speed of up to sixty miles an hour with automatic quality controls[185]; and (4) the discovery of new sources of raw materials possible after the invention of Thomas-Gilchrist basic process (Landes 2003). Of notable mention is the discovery of large oil (Saudi Arabia, etc.) and natural gas fields (Dutch field in 1959 and North Sea deposits shortly after) with petroleum refining and gas pipeline transportation.

German concentrated production: rail production once undertaken in nine different plants was concentrated into one; output of semis (bars, billets, slabs, and the like) into two or three. Every effort was made to make the most of locational advantages and minimize the disadvantages inherited with certain plants. Major gains in labor productivity were achieved: daily output per worker rose from 1.17 to 1.60 tons from September 1925 to August 1926; in steelmaking from 1.25 to 1.77 tons (Landes 2003). This was achieved through vertical integration of the leading iron and steel firms, which made it possible to effect and accumulate savings of energy at each stage of the production process: by standardizing, cleaning, and concentrating the raw materials before the converters or open hearths; by allowing the crude steel to harden only enough to permit reheating to a uniform temperature before insertion in the rolling mill; and by using a by-product, gas, to drive their own machines and even to sell their surplus to outsiders directly or in the form of electricity.

The French, instead of concentration, devoted their efforts at amalgamation, that is interpenetration between leading groups through participations, exchanges of shares, companies owned jointly by several groups and so on. To the point that Frederic Benham in 1934 states, "it

[185] An automatic control has become an industry in itself.

is impossible to state briefly real distribution of ownership". This complex interweaving of interests continues to characterize the French industry to this day.

European sentiment in 1944 was that the impetus provided by the Industrial Revolution was exhausted, the latest cluster of innovations, associated with electricity and motor transport, that had given the system a final push. The "S" curve of growth applied to the different branches applied to the general economy as well.

Education

The 3-IR brought economists to the fore with a concern for the business cycles and the theories that abounded. Keynes's *General Theory* offered the first plausible explanation for persistent unemployment and the classical model of general equilibrium composed of endogenous (intra-systemic variables) and exogenous (stimuli in terms of government intervention or similar acts of fiat). Economists such as Roy Harrod in 1939 assumed set capital-labor ratios and no technical progress (Landes 2003).

The salient characteristic of modern technology is the division and simplification of complex tasks, so that work that once called for a high degree of skill can be performed by the unskilled. Moreover, business enterprises have learned to replace or supplement slow and costly methods of man-to-man apprenticeship by group training programs, so that raw men, fresh in from the country can be turned into semiskilled workers in a matter of weeks to months. Some enterprises even prefer such new men to experienced workers on the ground that, while they have more to learn, they have less to unlearn.

Another assumption, the unskilled newcomers of the hardest, least attractive jobs in the economy releases manpower for higher posts. Every higher trained worker is supported by others less trained, both within the manufacturing enterprise and outside it. The correlation among labor supply, mobility, wages and rates of growth leaves much to be desired (Kindleberger). For example, throughout the 1950's Germany's major source of foreign labor was the population of refugees, first those who had fled west during and immediately after the war, then expatriates from East Germany and when the largest components of this group, the Italians, dwindled in number because jobs in their homeland, the German employers turned to Spain, Greece and Turkey. Industrial development calls up labor, not the reverse, in this scheme.

Education is leveraged by advancing science becoming rapidly common property. Scientists as a group are opposed to secrecy; on the contrary they are avid for publications, which is the key to fame and immortality. The findings appear in over one hundred thousand journals that are indexed, excerpted, summarized and translated so that no serious researcher need be ignorant of work done in other countries and languages. The principal exporter of knowledge, measured comparatively by the amount in royalties from other nations is the United Sates. Landes notes that scientific creativity is by no means an assurance of growth and economic success: there are too many slips between the idea and the profits. The effective utilization of scientific and technical knowledge requires a whole sequence of decisions and actions in the world of production and distribution[186].

Summary of the Third Industrial Revolution (1940 - 2000)

The Third Industrial Revolution primarily clusters around the innovations in the application of chemical and electrical sciences, specially automation, electronics, micro electronics, communications (optical, wireless and satellite) plus advances in the generation and delivery of land, sea, air, and space transportation power and atomic power.

[186] For example China's current rapid industrialization is made possible by the existing sequence of decisions and actions in the world of production, distribution and marketing of other countries.

These elements eventually coalesced in the heart of a larger, more complex process often designated as modernization, the combination of changes in the mode of production and government, in the social and institutional order, in the corpus of knowledge and in attitudes and values that make possible for a society to hold its own in the later centuries. That is: the ability to compete on even terms in the generation of materials and cultural wealth, to sustain its independence, and to promote and accommodate to future changes. Modernization comprises such developments as urbanization (concentration of population); a sharp reduction in both death rates and birth rates from traditional levels (demographic transitions) the establishment of an effective, fairly centralized bureaucratic government; the creation of educational systems (capable of socializing and training) and the acquisition of the ability and means to use an up-to-date technology.

APPENDIX I

THE NATURE OF EXPONENTIALOIDS

Born (1969) asserts that "the process of gathering and applying knowledge (technology), seen as the human race enterprise throughout extensive historical periods, must follow the law of exponential growth and can not be stopped." McHale (1972) adds "the exponentialities do not grow isolated one from the other, each though they are thus graphically represented." The grouping of several inventions that grow exponentially in McHale (1972, 1978) and García Bacca's (1989) work is done with the caveat that "the graphics in this study, even though they are presented in a coordinate system, do not have rigorous scientific value. Rather, they have a quantitative-qualitative (suggestive-indicative) value." Very much like the relation of height and weight is more than just height and weight to the medical practitioner, as observed in Chapter 1.

In order to indicate the originality of the invention, innovations and improvement processes, in relation to the significant field of other inventions in time which by definition are discontinuous (swimming, boat, sailboat, steamboat, nuclear boat) and in order to differentiate it from the purely singular analysis of processes and exponential curves of rigorous science, the term 'exponentialoid' was expanded and extensively used by García Bacca (1989). When applications (such as multiple inventions) are tied together by historical constraints, they prove capable simultaneously of specifying, on the one hand, the manner in which theoretical concepts or terms were created, used and applied and, on the other hand, some empirical content of the theory used itself.

The basis of this 'exponentialoid' concept is given further impetus by the discovery in Born's (1969) writings regarding his Novel Price winning work on the study of reality. Reality (all creation) massively-energetic of the universe maintains and sustains constantly all that there is. In this sense all reality is not “solid and in-destructively” but un-stable, dynamic although bounded and framed in a continuous sense, process in time and space which makes the ‘exponentialoid’ possible. Upon this foundation humanity is not ‘seated’ but ‘aseated’ (exists). This process affirms Born 1969, “is exponentialoid and unstoppable.” García Bacca (1989) expands on Born 1969, and states that “all processes are fundamentally physical, mathematical exponentialoid, and thus unstoppable.”

García Bacca (1989) furthermore asserts that an exponential growth, in the real world, can only be constrained by an exponential apparatus that restrains the growth. This has leaded us to a redefinition of the term sustainability as: the artificial force that opposes an otherwise exponentialoid growth force embedded in nature.

The elements or actors of change appear to be dissipated in the background that constitutes the building industry. There is also a growing awareness of the nature and magnitude of the challenges but not of the critical time line. Climate change events are beginning to accentuate the criticality of temporaloid element of the crisis. As the actors begin shifting their stance to attempt to ameliorate the exponentialoid nature of the current consumption and emissions, the question moves to firstly, what is the current (even if transitory) worldview of the industry and what does it need to become, and secondly, what are the current initiatives in the industry and what do they need to become in order to address the challenges.

Others, like Marchetti, have done significant work on exponentials that exhibit an “S” curve and merit mention. However, Marchetti’s work continues the algorithmic line of thought on an algebraic and algorithmic nature of the “S” curve, adding knowledge on the nature of the upper end of the exponential, when the curve reverses, i.e. in the event that it is ‘tamed’ in the parlance of our dissertation. Marchetti's theoretical work however fails to take into consideration the level of integration that we are proposing in this dissertation that is the level of vectorial like forces. Instead of adding another branch of theory at the upper end of the exponential, where it is 'tamed', we reserve an analysis of Marchetti's contributions when the exponentialoid moves from proto-theory to theory, then hypothesis, and has concrete methods for testing and verification. At which point we are in a better position to study the reverse exponential function (the full 'S') and at the same time the exponentialoid forces that have generated this shift.

APPENDIX J

SURVEY OF THE RESEARCH

IN THE BUILDING CONSTRUCTION INDUSTRY

As noted in the introduction, Koskela's writings provided a starting point for the theme of this dissertation, and motivated a pilot study on the nature of change in building construction to gauge the theme feasibility. This preliminary work is added to the dissertation because it sheds light on the current pre-paradigmatic state of research in the industry, the issues of fragmentation and anomalies, and the current initiatives to correct what is considered problems or deficiencies. Significant effort, energy and resources are being invested in these initiatives mostly geared towards garnering efficiencies and diminishing waste. The majority of these initiatives came prior to sustainability becoming an issue for the industry, addressed by LEED and others.

We divide this work into two parts; part 1 is our pilot study on the dynamics of building construction change according to several writings by industry leaders that point to a lack of theory which we extend in part 2 as a lack of a paradigm or worldview peculiar to building construction.

PART I

PILOT STUDY ON THE DYNAMICS OF CHANGE

In this work, which originally was a pilot study, we analyze the nature of change as observed in Koskela's and other writers using a format of four questions and Popperian logic when applicable. Popperian logic is based on the solution of a problem through an evolutionary process that incorporates the statement of a problem, a tentative theory regarding the problem and a solution, an error elimination stage, and the emergence of a residual problem with different characteristics. Note: *Italics* indicate thoughts and ideas from sources other than Koskela et al., which add insight to the issues.

J.1 Koskela, L., 2000, "An exploration towards a production theory and its application to construction"

Koskela's (2000) dissertation focuses on a search of a theory of production. His dissertation poses that a theory of production in building construction embodies the concepts of transformation, flow and value. The underlying premise, which he builds in subsequent papers along with other authors, is that construction productivity lags behind that of manufacturing. According to Koskela (2000), a crisis or a pre-crisis state exists in the construction 'industry.'

This lag of productivity is somehow related, according to Koskela (2000), to a lack of a theoretical foundation in construction. The lack of 'theory' is deemed to be a barrier to progress. However, the concept of 'progress' is not further defined[187]. Most of the concepts initiated and presented in Koskela dissertation are further developed in the forthcoming articles and therefore are not treated in detail at this time.

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[187] Bury, 1932, observed "The spectacular results of the advance of science and mechanical technique brought home to the mind of the average man the conception of an indefinite increase of man's powers over nature as his brain

a. Why were these statements made?

The empirical discrepancy between productivity in construction with that in other industries, such as manufacturing, prompted the statement that construction productivity lags behind that of manufacturing because, according to Koskela (2000), there is a lack of a theoretical foundation in construction along with the findings that construction peculiarities (on site, one-of-a-kind[188] and temporary organization[189]) are also 'determining factors' for this lag in productivity. Carassus 2004 further elaborates the characteristic of construction:

- The only production process in which products are static on site (immobile)
- Structures are prototypes adapted to each site and environment
- Structures have a very long life (relative to other manufactured products)
- Structures are adapted to evolving demands
- Institutional rules play an essential role.

The underlying concept of Koskela (2000) dissertation is that construction, even with its differentiating peculiarities, is an 'industry' (Groák, 1994; Bennet et al. 1998a; Bowley, 1966; Dubois and Gadde 2002) and as such could be directly compared with other 'industries'. This basic premise will be challenged in the following studies and observations.

b. What are the author's arguments and proposed solutions?

Koskela's (2000) arguments point to the fact that manufacturing techniques and frame is not directly translatable to construction due to its peculiarities, however if the imported manufacturing concepts of transformation, flow and value are incorporated as an integrated theory of production with the corresponding frame and techniques, a novel theory of production

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penetrated its secrets. The evident material progress which has continued incessantly ever since has been a mainstay of the general belief in progress that is prevalent today."

[188] Koskela 2000 calls it "prototype nature"; Drucker 1963: 'unique-product production'.

[189] Action is the essence of temporary organizations according to *Lundin and* Söderholm, 1995; Lundin, and Steinthórsson, 2003. Others: Harland et al. 1999; 'temporary multiple organization' (Cherns & Bryant 1984) or a 'quasi-firm' (Eccles 1981).

can be achieved (a la manufacturing and other industries) that is sensitive to the construction peculiarities, thus ameliorating the anomalies of discontinuities, constraints and variabilities.

c. What did he develop?

Koskela (2000) developed a methodology for highlighting construction peculiarities as well as the theoretical foundations for a theory of production, based on current practices (mostly transformation), some applications of the flow concept and the even rarer application of the value concept.

d. Gut reaction to particular issues.

Construction, as practiced, is broader than just a theory of production, and involves many other disciplines as acknowledged by Koskela (2000). A basic interpretation of Construction as an 'industry' is Koskela's (2000) basis for comparison with other industries such as manufacturing. Several studies have highlighted the similarities and differences between construction and ship building, electronics, aerospace (Green et al. 2004; Voodijk and Vrijhoef 2003) and automobile (Barber et al. 1998; Gann 1996) industries.

The differentiation (an understanding of construction as an industry of industries, rather than an industry) goes to the core of the problem. This differentiation, along with an unidentified construction paradigm may be the root cause that prevents a direct transference of other industries' techniques and theories to the construction sector in general as well as in particular projects.

If this is the case, importing technologies, techniques and frames from other industries may prove to be more difficult than anticipated, a continual source of not-fitting as well as not being able to yield, after adding complexity to the production process, the desired benefits. The peculiarities, the lack of theory of production, and the anomalies found in this comparative work point to a higher level of crisis: The need of identifying a building construction worldview and second identifying theories that better reflects building construction's background, field and peculiarities.

What Koskela (2000) points out in this paper, and in subsequent studies, is the presence of an anomaly. Construction embodies technologies (theory and action) with embedded scientific principles with anomalies and violations of expectations. Kuhn (1962) states that: "The manner in which anomalies, or violations of expectations, attract the increasing attention of a scientific (research) community needs detailed study, as does the emergence of the crises that may be induced by repeated failure to make an anomaly conform".

The issue of anomalies in building construction is further discussed in Ballard and Howell (2004): Howell et al. (1993a) central concept is the combined impact of work flow variability and dependence, and their implications for the design of operations. Howell et al. (1993b) central concept regards project ends and mean. In Ballard (1994), Ballard and Howell (1994), Howell and Ballard (1994a and 1994b) began publishing measurement data on work flow variability. The first data showed a 36% plan failure rate (i.e. 36% of assignments on weekly work plans were not completed as planned).

Later publications (Ballard and Howell 1998) expanded the data set, revealing a 54% grand average plan failure rate over a wide range of projects and project types. The data, according to Ballard and Howell (2004) represented what they term as a paradigm-breaking anomaly for traditional project management: Variability was in fact not spasmodic but persistent and routine. Neither was it small. What's more, according to the authors, analysis revealed that the large majority of plan failures were well within contractor control; contradicting the traditional assumption that variability was from external causes. This failure to actively manage variability became visible, as the corresponding need for active management of variability, starting with the structuring of the project (temporary production system) and continuing through its operation and improvement, a target of the Lean Construction trend and initiative. Koskela responds to the issue of this anomaly with a question, the subject of our next inquiry.

e. Applying Popper's (1972) method of conjecture and refutations:

$\boldsymbol{P_x}$ is the original problem, the current analysis identifies some of the most prominent Tentative Theories $\boldsymbol{TT_x}$ and Error Elimination $\boldsymbol{EE_x}$ techniques in practice and how that problem has evolved ($\boldsymbol{P_{x+1}}$) after the application of the TT and EE:

$\boldsymbol{P_1}$ = Construction productivity lags behind that of manufacturing; a crisis or a pre-crisis state exists in the construction 'industry.'

$\boldsymbol{TT_1}$ = A search for a theory of production that is based on T, F & V concepts

$\boldsymbol{EE_1}$ = Eliminate variabilities and the propagation of variabilities

$\boldsymbol{P_2}$ = Manufacturing techniques and frame stubbornly remain not directly translatable to construction due to its peculiarities

J.2 Koskela, L., 2003a, "Is Structural Change the Primary Solution to the Problem of Construction?"

Koskela (2003a) analyzes the causes for the well known problems of construction. A number of renewal initiatives such as industrialization, open building, design-build, partnering, re-engineering, Just in Time, Lean Construction and others are mentioned or analyzed. These initiatives imply or claim to be structural changes to the organizational pattern and or the flow of information and materials. Koskela (2003a) proposes a theoretical framework in order to discuss the issue of structural adequacy of these initiatives composed of three main theories (1) production, (2) management and (3) peculiarities in the building construction (Nam and Tatum

1988; Riis et al. 1992; Wortmann 1992a and b; Wortmann et al. 1997) industry as follows:

This framework is composed of a theory of production (incorporating the afore-mentioned concept of transformation, flow and value –T, F & V) and a theory of management and conceptualization (design, operations and production system improvements) and a theory of the peculiarities of construction (on site, one-of-a-kind and temporary organization). Based on this framework, a number of conclusions are drawn:

- Due to its peculiarities, construction is characterized by a high level of variability (a role of management is therefore to stem the penalties due to variability and the further propagation of variabilities).
- All renewal initiatives have given modest if not disappointing results.

Although Koskela (2003a) admits that the causal relation of such disappointments can not be established definitively, he suggests a neglect of changes at the level of operation and improvement as contributors to the lack of results. Therefore, he argues, that we "need to develop further the theoretical foundations or first principles, of production in general and especially in construction".

a. Why were these statements made?

Based on his dissertation work, Koskela (2003a) analyzes in this study a selected number of the trends and initiatives in construction that address the well known problems of construction. The problems or identified anomalies are the starting point of the argument that the well intended structural changes to the organizational pattern and or the flow of information and materials fail to achieve the desired results, looked at from the frame of his production theory (T, F & V) and the peculiarity theory (on site, one-of-a-kind and temporary organization)

b. What are the author's arguments and proposed solutions?

Koskela (2003a) proposed solution is to highlight the need to develop further the theoretical foundations or first principles, of production in general and especially in construction. The theoretical foundation, however, still looks up to Manufacturing for guidance, frame of reference and theories (Heim and Campton 1992; Hop and Spearman 1996).

c. What did he develop?

Koskela (2003a) thrust, in order to correct the neglect of changes at the level of operation and improvement as contributors to the lack of results, is to highlight the need for a more integrated theory of production based on the T, F & V concepts. The difficulty of establishing causality is acknowledged by Koskela (2003a) but the issues, even if they are muddied, are real and merit confrontation. Kuhn (1976) acknowledges the immense difficulties often encountered in developing points of contact between theory and practice, especially when the underlying paradigm does not allow for a clear and obvious relation of theory and practice, which may be the current case. What appears to be taking place throughout these studies is a preliminary identification of the puzzle or parts of the puzzle that could lead to paradigm identification, a subject that will be treated at length in Part II.

d. Gut reaction to particular issues.

Per Kuhn (1976) we see building construction search for an identification of deficiencies and anomalities and a concerted attempt to incorporate the technologies, frame and theories of production that continue to rub against the grain of a theory of construction peculiarities. Added complexity to a system without significant results is a sign that the working paradigm is not properly attuned to the circumstances; however as mentioned, there have been few attempts in this and other writings identified through literature search (Ballard and Howell 2003a; Groák 1994; Ranta 1993) at identifying an existing building construction paradigm.

e. Applying Popper's (1972) method of conjecture and refutations:

P_1 *= High level of variability perceived as an anomaly*

TT_1 *= Need for a theoretical foundation or first principle of production in general and specific of building construction based on theories of: 1. Production, 2. Management, 3. Peculiarities*

EE_1 *= Eliminate variabilities and the propagation of variabilities*

P_2 *= No clear and obvious relation between theory and practice but levels of complexity are added to the process; possible crisis and realization that current paradigm (building = manufacturing) can not resolve the anomalies and crisis.*

J.3 Koskela, L., 2002, "We Need a Theory of Construction"

Koskela (2002) elaborates that 'during the next decade, the formation of a theory of construction will be the single most important force influencing the construction industry'. This theory, he proposes will consists of two parts: First, a theory of production in general (T, F & V); Second the application of this theory to the characteristics and peculiarities of construction (on site, one-of-a-kind and temporary organization). On the most general level, Koskela (2002) identifies three possible prescriptive actions to a theory of production: Design the production system, control the production system (Gilbreths and Gilbreth 1922) and improvements on the production system.

Likewise, the author identifies three broad based 'deficiencies' in reaching a theory of construction. First, the chronic performance problems can more or less directly be associated to problems of theory. Second, in the lack of explicit theory, it has been difficult to implement methods of flow and value management in construction. Third, our efforts to develop construction, say through industrialization or information technology, have been hindered by the lack of theory.

These three themes are discussed in detail by Koskela (2002) within his framework for analysis. The idealized transformation view has a high idealization error in complex practice since 'certainty' does not prevail in construction. The inherent variability in production degenerates into mutual adjustments by the team on site. These inherent variabilities, again, are due to the peculiarities in construction. Koskela (2002) answers the question of why with: The various initiatives, such as 'industrialization' and 'information technology' in construction have often failed to produce the results intended because the fundamental problem is theoretical, Halpin (1993) echoes that 'we have not gone far enough in seeking a basic framework for the construction of facilities'. This study abruptly concludes that using the method of Last Planner (Ballard and Howell 1998a) can lead to manifest performance improvement by using transformation, flow and value theory as foundation.

a. Why were these statements made?

Halpin's (1993) and Koskela's (2002) progressive discovery of the cause of the problems and anomalies in construction lead to the statement that chronic performance problems can more or less directly be associated to problems of theory. A search for the pointers for a proper theory of construction continues, but appears to be limited by the frame of a theory of peculiarities.

b. What are the author's arguments and proposed solutions?

Last Planner appears to better integrate the T, F & V concepts and therefore is a better candidate in the eyes of Koskela (2002) to find and integrated theory of production.

c. What did he develop?

Koskela (2002) continues relating performance problems to theoretical problems which is a higher level of analysis than comparative performance of any one industry against building construction performance. Koskela (2002) also developed a method for establishing that current trends and initiatives for change are not radical and are not sufficient to engender significant structural changes.

d. Gut reaction to particular issues.

By highlighting that during the next decade, the formation of a theory of construction will be the single most important force influencing the construction industry; Koskela (2002) insinuates that there can be a total theory of construction and not just of production.

What we have here is described by Kuhn (1976) as a functioning but un-identified paradigm with rules and theories that are implicit but not explicit to the paradigm: "Rules[190] derive from paradigms, but paradigms can guide research even in the absence of rules." Lack of a standard interpretation or of an agreed reduction to rules will not prevent a paradigm from guiding research; indeed the existence of a paradigm need not even imply that any full set of rules exists (Polanyi, 1974). Paradigms may be prior to, more binding, and more complete than any set of rules for research that could be unequivocally abstracted from them. Normal science is a puzzle-solving activity that is highly cumulative enterprise, eminently successful in it s aim and the steady extension of the scope and precision. Distinction between discoveries or novelties of fact and invention or novelties of theory is exceedingly artificial. Discovery commences with the awareness of anomaly, i.e., with the recognition that nature (in our case, standards of practice) has somehow violated the paradigm-induced expectations (even though a paradigm has not been currently identified) that govern normal science…. And then continues with a more or less extended exploration of the area of anomaly and it closes when the paradigm theory has

[190] Theories are derived from rules and vice versa.

been adjusted so that the anomalous has become the expected. In construction, then, the standards of practice, anomalies with the espoused implicit theories, indicate that work needs to be done at all levels (practice, theory, rules) up to and including the identification of the existing paradigm in construction.

e. Applying Popper's (1972) method of conjecture and refutations:

P_1 *= Need a theory of construction*

TT_1 *= Need a theory and an applied theory: 1. Production in general, 2. Applied to building construction peculiarities*

EE_1 *= Design, control and improve production systems through Last Planner incorporating T, F, & V*

P_2 *= Certainty does not prevail in construction; on site team adjustments prevail; owner introduced chaos remain possible; current trends and initiatives are not sufficiently radical to render significant structural changes (i.e. need more manufacturing-like controls?)*

J.4 Koskela, L., Ballard, G., and Howell, G., 2003, "Achieving Change in Construction"

Koskela et al. (2003) is another study that further analyzes selected initiatives in construction regarding a perceived need for change. This paper begins by considering the scope of change needed, the big foundational ideas of change, as well as the initiation of change and keeping its momentum. The paper addresses four questions: First, which kind of change? Second, how those changes, in principle, are achieved? Third, presuming that construction is a fragmented[191] and fluid industry that can not be changed overnight, where should change start? Fourth how can the change momentum are maintained after the start?

Regarding the first query, which kind of change? According to Papert (2000) as quoted by Koskela et al. (2003) there are two approaches to renovating school of thought: The problem-solving approach (individual problem solution) and the systemic approach (how the whole thing works). The majority of the industry initiatives, according to Koskela et al. (2003) address individual problems in question: cost, productivity (time and cost), quality, safety, sustainability, etc… First, Solutions offered are not expected to lead to reform. Second, the suggested solutions address an underlying and 'obvious' cause of the problems through a pre-understanding of the nature of the problem or opportunity. "The pre-understanding is determined by a person's perspective within the guiding *professional*[192] paradigm" (*added professional to Koskela's statement*).

Koskela et al. (2003) analyzes four commonly understood solutions: structural, behavioral, communications (information management) and physical (machinery). Solutions to problems found in building construction exemplified by design-build as a structural response to the anomalies found in design-bid-build (known as traditional project delivery system). Structural change alone, according to Koskela (2003a) does not provide a solution, such as the structural change to project delivery system (PDS) by adding design-build to a model that originally was dominated by design-bid-build.

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[191] Dubois and Grade, 2002; Groák, 1994: "Construction can not be considered a coherent industry with definable boundaries and characteristic problems."

[192] *According to Kuhn, 1962, "Normal science, the activity in which most scientists inevitably spend almost all their time, is predicated on the assumption that the scientific community knows what the world is like." Because (the practitioner in a profession) joins men who learned the bases of their field from the same concrete models, his subsequent practice will seldom evoke overt disagreement over fundamentals. Men whose research is based on shared paradigms are committed to the same rules and standards for scientific practice.*

e. **Applying Popper's (1972) method of conjecture and refutations (to PDS)**

P_1 = *Systemic structural change required to project delivery system overriding concern with cost and resulting conflicts*

TT_1 = *One contract incentive for cooperation between design and builders*

EE_1 = *Unify design and builder into one contract to eliminate design-builder conflict reflecting on the owner (sidetrack the Spearing Doctrine where the owner through the designer provides documents that are adequate and sufficient for construction)*

P_2 = *Performance is equal to the traditional Design-Bid-Build in terms of cost, time, quality and sustainability results since the intrinsic mode of operation between the designer and the builder (their respective behavior, practice and cultures) do not change with a project whose peculiarities are one-of-a-kind and by differing team, therefore lack of efficient teamwork. Lack of integration of design and building cultures (behavioral approach) fail to achieve higher expectations on efficiencies and effectiveness.*

Behavioral approach is based on the mentality (attitude, behavior, practice, culture, etc…) and motivation of people as the root of the problem. Teamwork and Partnering are then suggested solutions to increase cooperation by identifying shared goals and establishing communication rules. *For example, we now add the process called Partnering to a Design-Build project team:*

***P_2* =** *(The new starting point) Design-Build Performance is relatively equal to the traditional Design-Bid-Build in terms of cost, time, quality and* *sustainability results since the intrinsic mode of operation between the designer and the builder (their respective practice, behavior, and cultures) do not change, therefore lack of efficient teamwork*

$\boldsymbol{TT_2}$ = *Agreement on Project Success Criteria increases teamwork efficiency (behavioral and inter-firm cooperation)*

$\boldsymbol{EE_2}$ = *Problem resolution scale (resolve problems at the lowest level of competency within a prescribed and strict time period)*

$\boldsymbol{P_3}$ = *Non-Binding Charter; Higgin and Jessop (1965) "any lack of cohesion and coordination is less the result of ill-will or malignancy on the part of any groups or [individuals] but more the result of forces beyond the control of any individual group and which are affecting all".*

In order to early identify the forces that are beyond the control of any individual, the stakeholders are then asked to participate in the process called Project Definition Rating Index (PDRI) which is analyzed later on and in an increased commitment-investment to improve Communications via technologies and make the owner aware of the chaos that changes can create during the process. Communications (Information and Communication Technology - ICT) is based on the premise, or the belief, that access to information and clarity of communications is the issue. However, according to Koskela et al. (2003), new technology does not change the more fundamental way work is done (Strassman 1997; Koskela and Kazi 2003). Ekstedt and Wirdenius (1994) study finds that construction behavioral-culture programs in comparison to manufacturing are easier to implement but with limited real results. Higgin and Jessop (1965) reports that lack of a cohesion and coordination is more the result of forces beyond control of any individual or group which is affecting all. That is, the system in practice (or context) has externalities that determine behavior. Trying to change behavior (on-one-of-a- kind and by a temporary organization) is more or less futile. *The following is an example, an analysis of ICT using the same format:*

***P**$_{ict1}$* **=** *Access to clear, correct, complete and timely information in an ambience of deteriorating design documentation and quality due to reduced fees (Tilley and McFallan, 2000)*

***TT**$_{ict1}$* *=One platform, web based, with shared real time information and accessible to all stakeholders on demand increases efficiencies by reducing discontinuities, constraints and variability in the planning phase. Planning and execution efficiencies are deemed synonymous.*

***EE**$_{ict1}$* *= Eliminate duplication of outdated information and avoid discontinuities and variabilities in document generation and use*

***P**$_{ict2}$* *= Difficult to implement due to the cost and the learning curve of one platform when stakeholders are accustomed to their own platforms. For ICT benefits to be unleashed there must bee: upstream supporting organizational changes to owner, financial institutions, and code officials; downstream to each sub-contractor, supplier and vendor. A translator of existing platforms with one web-based platform so that each stakeholder can use both is prohibitive due to the peculiarities of one-of-a-kind and temporary organization (*Lundin and Söderholm 1995; Lundin and Steinthórsson 2003).

Physical (machinery) problems are associated with the low level of mechanization and either industrialization (off-site pre-fabrication) or on-site construction robotics and automation. *The belief behind this issue is that industrial production is more efficient as shown in the following example:*

***P_{m1}* =** *Low level of mechanization*

TT_{m1} = *Industrial production is more efficient through the use of robotics and automation that eliminates human induced variability and waste thus bringing the efficiencies in planning to bear directly with execution thus making real the previous theory that planning and execution are synonymous*[193]*.*

EE_{m1} = *Eliminate down time, by robotics that can work 24/7/365, control of variables and elimination of internal and external discrepancies, conflicts and the resultant waste.*

P_{m2} = *coordination issues with other trades remain unless the whole project can be done with robotics and automation. ICT flow through one-of-a-kind project, on site and by differing teams requires a universal platform where activities and parts brought by suppliers and vendors are integrated, that is, the whole production template is changed. Apparently this radical change is cost prohibitive due to the project peculiarities, especially one-of-a-kind, where increased complexity and cost does not yield sufficient project benefits and efficiencies for the required investment in time and learning.*

Before proceeding with answering questions two, three and four, the authors discuss the issues of production paradigm (Ranta 1993; McLoughlin 1999), theories of production and production templates. The authors conclude that "industrial history indicates that improvements in the range required in construction happen only when the whole production template is changed". This production template change is based on new big ideas, new theories (*and we add 'new paradigm'*).

Koskela et al. (2003) conclude the answer to the first query, by stating that current trends and initiatives are mainly of the 'individual (segmented) problem solving approach' and are based on a divide and conquer mentality or more specific on a quality assurance principle of constraint removal, the current mental model of production.

The next query posed is: How can the changes, in principle, are achieved? Koskela et al. (2003) accept the principle that a systemic change is needed in construction, then, how in principle can a systemic change be achieved? Construction places its hopes on external ideas as drivers for change, such as industrialization or ICT. Regarding industrialization the target is to transform construction into manufacturing. Regarding ICT the premise is that increase use of data sharing via computers/Local Area Networks (LAM) /Wide Area Networks (WAN - internet) will lead to organizational renewal and eventually increased efficiencies and waste reduction. However both of these initiatives are deemed to increase complexity without benefits at this time. The observation that 'something is wrong', that there are 'anomalies' in the current construction paradigm are echoed by Butler (2002): "Construction has become more and more complex. Disciplines have divided and sub-divided and whole new trades have sprung up. Contractors seldom self-perform a substantial portion of the work. To make matters worse, subcontractors are beginning to do the same by hiring their own subs to do the work" Allen (1996).

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[193] The underlying premise is that "perfect – correct, complete, coordinated and timely' planning by both design and construction management translates into 'perfect' execution.

The result of this downstream activity is according to Bennet and Ferry 1990, a "total lack of production control". Tilley and McFallan (2000) have documented that Design and Documentation quality had decreased at the same time that project cost, time and inter alia disputations, lower quality and lack of attention to sustainability have increased (Koskela 1992; Howell and Ballard 1997; Koskela 2000). This is attributed by Koskela et al. (2003) to a progressively more forceful application of the transformation model of production: decomposition of the total transformation (the project) into smaller transformations and eventually tasks and the minimizing the cost of each task independently on the basis of the lowest price. This leads to two major problems: First in the case of planning (design plans and management plans for construction) the completeness, correctness, coordination and timeliness of the documents tend to decrease with decreasing fees. Second, as planning is pushed down-stream, the amount of coordination of production control and corresponding variability tends to increase beyond what the project budget can bear.

The construction model (Ballard and Howell 1998a) is a model of project control, not production control according to the 'contractual agreement' thus construction can be said to have no theory of production control proper. Tavistock Institute (1966) finds that the disparity of the formal system (contracts, documents, Project Management, Schedule, Cost Estimating, etc…) and the informal system (on site, varying team, management of uncertainties, variabilities, discontinuities, tasks independence, sub-sub-contractors etc…) in relation to the total task is pointed out as the root cause of all the problems. The informal system manages a climate of endemic crisis which is self inflicted and self perpetuating. Two solutions are proposed, ICT and behavioral approaches, as previously seen. However in most cases the participants end resigning that no meaningful, real change is possible.

Koskela argues that a change from transformation to a flow template can be achieved through deliberate design and imitation. In a practical way, theories should be used for explaining why problems exist and how they can be avoided (Koskela and Ballard 2003). Experimentation should then be used for translating theories into practical methods and tools.

The next query approached is: Where should change start? Two approaches to this query are presented: First, owner's procurement strategy based on performance, rather than cost. Performance is considered the beginning where the scope of the project is created. Second, working with those that actually manage production, (the end where the product is created: Design, pre-fabrication, erection, on site construction and site personnel). Koskela et al. (2003) argue for starting at the end because this is where cost, time, quality, etc… are concretely formed and because what we learn can be taken upstream.

The final query is: How can change momentum be maintained? The authors address two interrelated levels of change momentum maintenance: Firm level and Industry level. At the firm level (organizational change Beer and Nohria 2000) one approach focuses on top-down changes on formal structures and systems to mainly create economic value (thus termed Theory E). *For example: Beck Dallas Office method of integrating with architecture was to buy an Architectural Firm in 2000 with a limited practice and integrating it with the construction firm with a diverse practice, but through the focus of innovating on an ICT platform called Destini.*

The other approach focuses on the development of a culture of high involvement and learning in a participative manner (hence Theory O). *For example, Beck Atlanta District method of integrating with architecture was to acquire two in-house architects in 2000 with the task of developing an integrative culture to work with other architectural firms with diverse practice in a virtual organization using a matrix approach to risk and management. This was perceived as* *a more challenging task but if it could be made to work, having a greater potential since the types of architecture were not limited by in-house talent and experience but that of the virtual organization.*

Koskela et al. (2003) proposes using both E and O simultaneously creating 'small wins' (Weick, 1994) with each step by step change. Through controllable opportunities of modest size that produce visible results and serve as background to identify next possible problem to solve. A pattern is thus built that attracts allies and deters opponents. The iterative process of problem-solving changes needs to be scrutinized prior to experimentation by the following questions:

- Is there a Plausible Explanation (PE) – at a sufficiently detailed level – as to why the candidate solution would work?
- Is there Empirical Evidence (EE) showing that the candidate solution brings the benefits sought for?
- Is the candidate solution self-standing or does it requires surrounding (ancillary - AN) changes for working efficiently and providing manifest benefits?
- If the solution is imported from another domain: Has it been conceptually and Empirically Confirmed (EC) that the solution works in the context of construction?

This iterative process appears similar to Popper's (1972) philosophical method of analysis (Conjecture and Refutations) and applicable mostly to individual (segmented) rather than systemic cases. Because it is applicable to individual cases, the process following iterative process may now apply:

$\boldsymbol{P_1}$ = *Original Problem*

$\boldsymbol{TT_1}$ = *Tentative Theory*

$\boldsymbol{EE_1}$ = *Error Elimination*

PE = *Plausible Explanation (why it should work)*

EE = *Empirical Evidence (will achieve expectations)*

AN = *Self-standing/Ancillary effects*

***EC** = Empirical Confirmation of transferability*

***P_2** = Emerging Problem*

In conclusion, Koskela et al. (2003) argue that (1) a systemic change (not problem specific oriented change) has to be achieved for eliminating root causes of the problems, (2) external ideas or impacts (industrialization and ICT) are not the solution but a 'new big idea' for managing construction has to be found, read a new paradigm, (3) instead of upstream structural changes (contractor and organizational top-down) we should look at operational changes downstream that create the end product and work backwards, (4) changes do not occur automatically even in favorable environment, but through small wins in a fragmented milieu that gather strength and eventually achieve system-wide changes in an entrepreneurial atmosphere.

Why were these statements made?

Based Koskela et al. (2003) study, current trends and initiatives are not radical nor sufficient to engender a structural change in the industry, but it remained to be established what kind of change is needed and how can these types of changes be implemented and maintained. The paper center around the research needed to answer four well posed queries with the a priori presumption that construction is a fluid industry that can not be changed overnight, that incorporates a cursory definition of 'fragmented'. A better definition of how construction is understood to be fragmented or fluid is needed beyond what is available though literature search and a recommended future work or even a possible dissertation topic.

This proliferation of trends and initiatives is not uncommon in a pre-paradigm identification scenario, according to Kuhn (1962): Both during pre-paradigm periods and during the crises that lead to large-scale changes of paradigm, scientists usually develop many speculative and unarticulated theories that can themselves point the way to discovery. Often, however, that discovery is not quite the one anticipated by the speculative and tentative hypothesis. Only as experiment and tentative theory are together articulated to match does the discovery emerge and the theory becomes a paradigm.

a. What are the author's arguments and proposed solutions?

Koskela et al. acknowledge that a 'big foundational idea change' needs to take place if the "construction industry" is to be changed significantly. After analyzing the two change approaches according to Papert 2000, problem-solving approach (individual problem solution) and the systemic approach (how the whole thing works) Koskela et al. (2003) concludes that a problem-solving approach, from the bottom-up, that acknowledges how things are done may be indicative of a practice, technique or craft that could be analyzed as for pertinent theories that then can be incorporated with an overall frame. However the validity of this approach must be confirmed by an equally well adjusted flow between paradigm-rules-theories-practice in both the down-stream and up-stream mode.

The argument is then made that industrial history indicates that improvements in the range required in construction happen only when the whole production template is changed". This production template change is based on 'new big' ideas, 'new theories'. These statements are pointers to a need to identify the reigning paradigm and establish once and for all what kind of industry is building construction, if the term fits and applies, or if not what is building construction based on the existing paradigm. Confronted with anomaly or with crisis, Kuhn (1962) state that scientists take a different attitude toward existing paradigms, and the nature of the research changes accordingly. The proliferation of competing articulations, the willingness to try anything, the expression of explicit discontent, the recourse to philosophy and to debate over fundamentals, all these are symptoms of a transition from normal to extraordinary research.

1. In principle, a new phenomenon might emerge without reflecting destructively upon any part of past scientific practice.
2. Or a new theory might be simply a higher level theory than those known before, one that links together a whole group of lower level theories without substantially changing any.
3. Or in an evolutionary sense new knowledge would replace ignorance rather than replace knowledge of another and incompatible sort.

From Koskela et al. (2003) statements, it appears that his position aligns with Kuhn's statement number 2 abovementioned. We argue, on the other hand, that statement number 3 is more applicable: Ignorance of what is the prevailing and active construction paradigm, a new basic and probably very simplistic knowledge, such as the earth is round not flat, or that the sun is the center of the universe and not the earth may be end up as a better fit for the anomalies and current crisis.

What did he develop?

Koskela et al. (2003) developed a method for analyzing four commonly understood solutions in the areas of structural, behavioral, communications (information management) and physical (machinery) that we translated into Popper's Analytical Process also called an iterative method of conjecture and refutations. Popper's process has been found helpful in identifying by category (Tentative Theory and Error Elimination) the components of a proposed solution on the way to problem application and resolution (or in this case emerging problem with unresolved or new issues).

Koskela et al. (2003) developed, or elucidated, the issues surrounding increasing complexity of the proposed trends and initiatives without significant result which brings to mind Kuhn's (1976) statement: "When complexity increases far more rapidly than its accuracy or benefit and that a discrepancy corrected in one place is likely to show up in another may lead to a similar proclamation as that of Alfonso X that if God had consulted him when creating the universe, he would have received good advice, or Copernicus comment in *De Revolutionibus* that the astronomical tradition he inherited had finally created only a monster". "Proliferation of versions of theories is a very usual symptom (or concomitant) of crisis."

The acknowledgement that construction is a fragmented industry is one of the more significant insights or statements made along with the differentiation of formal planning as per Project Management and informal planning as per the job trailer executors, operators. The discrepancies, variabilities and constraints between these two modes of planning (actually he calls Project Management planning and on-site executing or implementing) along with the concept of fragmentation[194] in the construction 'field' is significant to an understanding of actual operations and may lead to insights on the existing paradigm.

b. Gut reaction to particular issues.

To the issues of discontinuities, variability, constraints, peculiarities, lack of theory we can now add the issues of fragmentation and the anomalies innate in current concepts of planning in our quest for a building construction paradigm.

J.5 Koskela, L., and Howell, G., 2002a, "The Underlying Theory of Project Management is Obsolete"

This study advances that there is a theory of project and a theory of management as espoused in the PMBOK (Project Management Body of Knowledge) guide by the Project Management Institute (PMI) (Duncan 1996). Koskela analyzes the anomalies (deviations from assumptions or outcomes) between theory and practice to conclude that a wider and more powerful theoretical foundation is needed. Mastery of theory, according to Fugate and Knapp (1998) is the single

[194] Carassus 2004 observes: Fragmentation is determined in particular by three factors: fragmentation of the order, the degree of technical complexity and the capital intensity of the activity. Each segment of the 'sector system' has large number of companies. This he calls differentiated fragmentation.

most important factor distinguishing a profession from a craft. Mastery of theory along with mastery of practical skills of the field is the hallmark of a professional.

Kloppenburg and Opfer (2000) analyzed forty years of project management and found an omission, silence, of the theoretical. Koskela and Howell (2002b) contend, however that there is an implicit and narrow theory which may explain the frequent failures (Kharbanda and Pinto 1996), lack of commitment towards project management methods (Forsberg et al. 1996) and slow rate of methodological renewal (Morris 1994). A theory consists primarily from concepts and causal relationships that relate those concepts (Whetten 1989) and in the case of construction is prescriptive, revealing how action contributes to the goals set to it. On the most general level there are three possible actions: design of the systems employed in designing and making; control of those systems in order to realize the production intended; and improving of those systems.

Koskela and Howell (2002a) argue that the underlying theory of project management is essentially based of economic transformation theories where in addition to the ten PMBOK core planning processes (scope planning, scope definition, activity definition, resource planning, activity sequencing, activity duration estimating, cost estimating, schedule development, cost budgeting and project plan development) there are one executing process, and two controlling processes, thus Managing as Planning with an effect on part per Johnson and Brennan (1996). By assuming that translating plan into action is the simple process of 'issuing orders', it takes plan production to be essentially synonymous with action. Through work authorization (like job dispatching in Manufacturing – Emerson (1917); selecting a task (per plans); and communicating the authorization) and a feedback mechanism of performance reporting (Hofstede 1978; Ogunnaike and Ray 1995). Management at the operations level consists on the centralized creation, revision (updating) and implementation of plans.

Transformation theory according to Koskela and Howell (2002a) presents anomalies when theory encounters the real world (empirical world). In order to evaluate to evaluate a theory, a comparison is made between alternative theories such as flow and value theories. In summary, the major difference between transformation view and the flow view (i.e. JIT Gilbreths 1922; Hopp and Spearman 1996) and Lean Production (Alarcon 1997; Ballard and Howell 1998a; Santos 1999) is that the latter includes 'time' as one attribute of production. Because 'time' is affected by the uncertainty (Howell et al. 1993a) in the production process as well as the interdependencies between tasks, the focus is directed towards uncertainty and linkages which are not acknowledged in the transformation view. The flow view basic trust is to eliminate waste from the flow process, that is, through reducing uncertainty whereas the transformation view accepts existing uncertainty. *For example JIT and Lean production can be analyzed as follows*

P_1 *= Management as planning with execution (dispatching: selecting tasks and authorization) and controlling via feedback (thermostat model) closes a loop that leaves out the element of time and uncertainties and is wasteful in practice*

TT_{1a} *= Time compression leads to waste reduction*

TT_{1b} *= Variability reduction leads to waste reduction*

EE_1 *= Planning when implemented consists of tasks in time: eliminate time associated uncertainties (**TT_{1a}**) as well as uncertainties associated by the interdependence between tasks (**TT_{1b}**).*

P_2 *= Externalities and peculiarities continue to introduce uncertainties,* *variability. Accommodation of JIT and Lean production depends upon some extent to production excess capacity and availability on demand. The issue remains on production and material flow control with no attention to the issue of value generation.*

The value generation view is based in reaching the best possible value from the point of view of the customer (client) (Shewhart 1931; Cook 1997; Suh 2001). The major difference between the transformation view and the value generation view is that the customer is included in the latter. Whereas the transformation view assumes that customer requirements exists at the onset (scope of work definition) and can be decomposed along with the work, the value generation view admits that at the onset, customer requirements are not necessarily available or well understood and that the allocation of 'value' requirements to different parts of the project is a difficult problem (specially given a fixed budget). For example Project Definition Rating Index (PDRI) was created precisely to address the issue of scope and value early definition and team understanding of the owner and of each other's perspectives. *An analysis of PDRI follows"*

P_1* = *Need to eliminate uncertainties created by lack of scope definition and misunderstandings (Howell et al. 1993).

TT_1 = *Early definition of scope and clear communication and affirmation of understanding of the scope by stakeholders improves performance and achieving best value for the owner with less wasted effort.*

EE_1 = *Early definition of scope by all stakeholders: eliminate time associated uncertainties as well as uncertainties associated by the misunderstanding of interdependences between tasks. Commissioning involvement at the front end is required to assure that the specified performances can be measured and tested at* *the end of the project for a comparative analysis of expectations and delivery.*

P_2 = Sahlin-Anderson (1992) *argue that commitments, dependencies and expectations developed in the process of interactions, (the project as experiment) are what drives the project towards realization. Up-front planning does not relieve the issue that there are two separate organizations (*Applebaum 1982*), one for the management function and one for getting the work done and behavioral and cultural issues prevent the two organizations from coordinating their work as they are characterized by different goals and viewpoints.*

Performance based specifications is also a current initiative that attempts to nail down the level of quality for the design, construction and commissioning processes, thus addressing indirectly value generation issues. *Value generation can be analyzed as follows:*

***P_1* =** *Owner desires best value*

TT_1 *= Fulfillment of owner's requirements and wishes lead to value generation.*

EE_1 *= Early definition of scope by all stakeholders: eliminate time associated uncertainties as well as uncertainties associated by the misunderstanding of interdependences between tasks. Commissioning involvement at the front end is required to assure that the specified performances can be measured and tested at the end of the project for a comparative analysis of expectations and delivery.*

P_2 *= Each major value item has to be identified and a comparative analysis performed in a matrix system to determine the best possible combination of value, cost, time and quality. This is a major effort in one-of-a-kind projects that have team variability and may not be able to accommodate the front end costs. Later decisions may affect the overall plan, thus continual update is necessary, increasing the cost of a best value* *performance approach. It is also noted that "generally" it is not possible to maintain a complete up-to-date representation of the current circumstances and the plan to change them. Tacit knowledge and improvisation remain a key component of execution (Fondahl, 1980)*

Koskela (2000) argues that these three views (T, F & V) are not alternative, competing theories, but rather partial and complementary. What is needed is a production theory and related project management theory that fully integrate the transformation, value and flow concepts.

In this study, the authors also contrast the theory of control named the thermostat model with that of a continuous learning and improvement model. The second theory is based on a project plan being a hypothesis that is tested through the project itself that becomes an experiment characterized by the peculiarities of one-of-a-kind by a varying team on a particular site and therefore with multiple variables. *The final product is a comparative analysis of the project (experiment results) with the hypothesis. (*Shewhart and Deming 1939*).*

***P_1* = *Plans are hypotheses to be tested in a project experiment*

TT_1 = *Building Design and Construction is a dynamic process of acquiring knowledge*

EE_1 = *An attitude of controlled experimentation with the plans as a guide and with defined purposes.*

P_2 = *Variable team infers that lessons learned are not irreversible or transferable to the next project team which may not have interest and receptivity to issues that have not become critical.*

The authors argue along with Wiest and Levy (1969) that it is questionable whether the precedence relationships of project activities can be completely represented by a ‘non-cyclical’ network graph in which each activity connects directly into its immediate successors. The overall effect of revisions, repairs and rework on large projects is significant (Cooper 1993; Friedrich et al. 1987).

In conclusion, Koskela and Howell (2002a) state that without an underlying theory, it is almost impossible to have access to the deficient assumptions or argue about methodology. Project management as a discipline is in crisis, states Koskela, and a paradigm change, long overdue, has to be realized. Koskela and Howell (2002a) proposes two routes for a new theoretical foundation: (1) based on new theories on operations management, new project management methods may be developed and tried out and (2) advance practice may be consolidated and explained theoretically.

Why were these statements made?

Koskela and Howell (2002a) analyze the theory of project and the theory of management and continue to issue a call that a wider and more powerful theoretical foundation is needed since without an underlying theory, it is almost impossible to have access to the deficient assumptions or argue about methodology.

a. What are the author’s arguments and proposed solutions?

In this paper the theory of ‘project’ assumes the same elements of the previously mentioned theory of ‘production’. Koskela and Howell (2002a) may be purposefully equating ‘project’ to ‘production’, although this direct relation is not made explicit other than describing a theory of ‘project’ by the T, F & V components also used in a theory of production.

b. What did he develop?

Under the umbrella of an underlying theory of Project Management, Koskela and Howell (2002a) group the following current topics as taught in academia: (1) a theory of project, (2) a theory of management, (3) a theory of planning, (4) a theory of execution and (5) a theory of controlling. All these five theories are then contrasted with the empirical evidence gathered from practice in order to define anomalies. In his Exhibit 2, the authors state that deficient definitions of planning, execution and control as well as an implicit theoretical basis are the root causes of the three types of problems previously mentioned. The final call is for a more intimate relation between theory and practice must be created, in order to placate the serious anomalies found.

c. Gut reaction to particular issues.

The statement that "Mastery of theory, according to Fugate and Knapp (1998) is the single most important factor distinguishing a profession from a craft" is applied to the theory of project management. This study does not acknowledge that the divisions within the fragmented construction field have fully developed theories according to their professions. For example there is a well developed theory of structures and theory of mechanics (that include Climate comfort as well a physical comfort such as plumbing). Other well developed theories within the field of construction are vertical circulation, building facades, etc…

The authors are looking at the narrow scope of putting the project together and by brining the issue of planning have done a great service to elucidating a fundamental principle that: plan production to be essentially synonymous with action. In the past when architecture or design became differentiated from construction, the same critique was made on the design plans, assumed to be essentially synonymous with action. Now we have another layer of planning, construction management planning, which is also essentially synonymous with action. And it is even argued that sub-contractors have become another layer of sub-contractor planning that is also essentially synonymous with action further relegating actual production and assembly to a sub-sub echelon. "The delegation appears to be a winding road to China…" The principle that plan is essentially synonymous with action may have significant role in the actual paradigm, as we shall explore later.

There is no doubt that there is a crisis (when we compare building construction productivity with that of other industries) and a blurring of where the solutions may be found (such as a body of theories that can be tested and refined). Koskela and others are voices documenting the anomalies and the magnitude of the crisis. However the proposed solutions remain within the existing and unidentified paradigm and apparently something is not working and at odds. The unidentified paradigm in building construction may be an implicit and deeply embedded paradigm difficult to grasp although once identified becomes obvious. This assumption is made because the building construction practice is so ancient (building a shelter from the forces of the natural environment), and predates any figment of a conscious understanding of science, technology, techniques, craft, frame of reference, field, background and the concept of paradigm.

According to Kuhn (1968, 1976): "All crises begin with the blurring of a paradigm and the consequent loosening of the rules for normal research". In our case it could be the blurring of the embedded building construction paradigm with the assumption that it is the same or synonymous with the industrialization paradigm (Ballard and Howell 2003a). In this respect research during crisis very much resembles research during the pre-paradigm period, except that in the former the locus of difference is both smaller and more clearly defined. And all crises close with the emergence of a new candidate for paradigm and with the subsequent battle over its acceptance. A battle that is a reconstruction of the field from new fundamentals, a reconstruction that changes some of the field's most elementary theoretical generalizations as well as many of its paradigm methods and applications.

It is, Kuhn (1976) thinks, particularly in periods of acknowledged crisis that scientists have turned to philosophical analysis as a device for unlocking the riddles of their field and the thrust of this dissertation. Scientists have not generally needed or wanted to be philosophers. Indeed, normal science usually holds creative philosophy at arm's length, and probably for good reasons. It is no accident that the emergence of Newtonian physics in the seventeenth century and of relativity and quantum mechanics in the twentieth should have been both preceded and accompanied by fundamental philosophical analyzes of the contemporary research tradition. (Dugas 1950; 1954).

The identification of anomalies in the theory and practice of building construction is a major contribution to the field of knowledge. There are only three types of phenomena about which a <u>new theory</u> might be developed, according to Kuhn (1962):

- Phenomena already well explained by existing paradigms, however in most cases nature does not provide ground for discrimination.
- Those whose nature is indicated by existing paradigms but whose details can be understood only through further theory articulation but not invention.
- The recognized anomalies whose characteristic feature is their stubborn refusal to be assimilated to existing paradigms and thus give rise to new theories.

Thus it is this third type of phenomena that is of interest to identify first and foremost the existing paradigm in building construction.

J.6 Koskela, L., and Vrijhoef, R., 2001 "Is the Current Theory of Construction a Hindrance for Innovation?"

Koskela and Vrijhoef (2001) state that the prevalent theory of construction which is implicit, deficient, and is a hindrance to innovation. Without explicit theories, it has not been possible to access core ideas of concepts and methods of other templates, such as manufacturing and re-create them in a construction environment. The driver of least cost, as in the transformation model that decomposes projects into parts and later into tasks abstracts away the issues of uncertainty and time, creating a scenario of 'myopic control' and inflated variability. The atmosphere at project execution becomes one of handling crisis and a divorce between plan and execution impedes top-down and bottom-up systematic learning and capturing problem solving lessons learned for posterity thus impeding implementation of innovations. Slaughter (1998) presents the following typology of innovation[195]:

- Incremental: small change with limited impacts on surrounding elements
- Modular: a more significant change in the basic concept but with limited impact on its surroundings.
- Architectural: small change in the respective component but with many strong links to other components
- System: multiple linked innovations
- Radical: a breakthrough in science or technology that changes the character of the industry.

Lillran (1995) argues that organizational innovations do not transfer well in their original setting over industrial borders. But the core ideas or concepts of the organization innovation must be abstracted and re-created in an application that fits local conations. Koskela and Vrijhoef (2001) state that in consequence of the absence of 'radical' managerial innovations, present practice of construction management is characterized partly by methods originating from the craft period with some centralized control brought from manufacturing left-over. Trade (the craft mentality) the authors state, has no incentive to share learning experiences for the sake of re-applying them in future projects by a differing crew for the sole benefit of the general contractor. Problem solving becomes innovation when solutions found are retained and re-applied to future projects in a systematic mode. And along the same lines, Pries and Janszen (1995) pose that innovations come from the supply base.

High level of inherent variability brought about minimizing the cost of each task in the transformation view, and each task input increasing the number of required interactions (exponentially) results in a corresponding increase in complexity, discontinuities and variabilities.

In conclusion, the authors state that a new production template (of radical innovation) that is based on an explicit theory of production and with full recognition of construction peculiarities is needed.

a. Why were these statements made?

In previous papers Koskela advanced the proposition that change in building construction should come from the bottoms-up. However there is a problem of harnessing the knowledge of actual practice due to the inherent variability of the industry. Koskela and Vrijhoef (2001) in this article bring to light taxonomy of change and the identified need to harmonize theory with practice but with practice leading the way. A method then is sought to accomplish this task with the building construction.

b. What are the author's arguments and proposed solutions?

The authors re-affirm that the prevalent theory of construction which is implicit, deficient, and is a hindrance to innovation. The prevalent theory is implicit, therefore, methods of other

[195] Freeman, 1989 defined innovation as: use of non-trivial change and improvements in a process, product or

templates, such as manufacturing and can not be re-created in a construction environment. Hence, there is a perception of a draught of innovations from the exterior as well as from the interior due to the peculiarities of construction, namely temporary organization. Innovation, as presented proposed solution encounter a solid wall by the fact that trade (the craft mentality) the authors state, has no incentive to share learning experiences for the sake of re-applying them in future projects by a differing crew for the sole benefit of the general contractor.

c. What did he develop?

The authors developed the rationale for a need of a new production or project template. Without knowing, what the authors have developed is a need for identifying the current paradigm and perhaps then working on a new paradigm for building construction.

d. Gut reaction to particular issues.

The most significant statement in this paper is the acknowledgement that there exists a Trade (the craft mentality) that has no incentive to share learning experiences for the sake of re-applying them in future projects by a differing crew for the sole benefit of the general contractor. This statement may be foundational to identifying the existing paradigm or the underlying culture of that paradigm. Pries and Janszen (1995) posing that innovations come from the supply base is in contrast with the theories of project and the theories of management as well as the theories of design that are all based on planning, controlling and execution directed from the top-down. This finding is another case of the inherent anomalies found in building construction that is aggravated by the peculiarity of temporary organization which makes it different from other industries.

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system that is novel to the institution developing the change.

J.7 Vrijhoef, R., and Koskela, L., 2005a "Revisiting the Three Peculiarities of Production in Construction"

Discusses the previously mentioned peculiarities based on the findings of seven practical examples as to whether construction must and can always be improved by resolving the peculiarities and at what cost. It is concluded that the peculiarities should be resolved when they are not needed. However, before a decision is made, the additional costs or even the potential value loss that may be caused by peculiarities must always be related to whole life costs and value of the object built, and the extra costs and efforts for resolving the peculiarities[196].

a. Why were these statements made?

After several years of wrestling with the issues of building construction peculiarities the lack of fitness with the manufacturing and industrial paradigm has brought a resignation that perhaps the cost and effort for eliminating the peculiarity (or peculiarities) is not proportional to the benefits when considering the whole life cost of the object built. Most of the studied cases are in the residential area, where components, although variable, can be made to fit a particular module and thus the amelioration of a peculiarity or two.

b. What are the author's arguments and proposed solutions?

The solution is to live with the peculiarity of construction, and put aside the quest for the "BIG IDEA" that would make construction be like manufacturing.

c. What did he develop?

A comparative analysis was developed of differing examples.

d. Gut reaction to particular issues.

The issue of finding construction unique existing paradigm remains.

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[196] See heuristic principles.

PART II

OBSERVABLE WORLDVIEW CHARACTERISTICS FROM THESE INITIATIVES

This section begins with a brief exposition of an understanding of a pre-paradigm from Kuhn's (1962, 1976 and 2000) writings as it may be applicable to building construction. The elements of a possible existing paradigm in building construction is discerned from Koskela's selected writings (especially where anomalies and crisis are noted) and compared with selected concepts of a paradigm from Kuhn's writings. The underlying attitude for using Koskela et al. writings as source is derived from Kuhn (1962) statement: "Often a paradigm emerges, at least in embryo[197], before a crisis has developed far or been explicitly recognized". Analytical thought experimentation from researchers exposes, sometimes unwillingly, the paradigm to existing knowledge in ways that isolate the root of crisis with clarity otherwise unattainable.

Two major underpinnings of a paradigm are identified afterwards, a Philosophical base that comes from a historical hermeneutical analysis and a Legal base that comes from early legal precedence in the US. Afterwards, using Palmer's Schema (2002) as framework, building construction 'industry' categorization is exposed, as an anomaly that contributes to the current comparative dilemma.

Finally the above mentioned logic culminates in an existing and a proposed building construction paradigm. The search of a new paradigm for building construction begins with a new proposed understanding of the project and planning concepts that lead to an alignment of titles to better correspond with function (this is not significant, but helpful in clarifying and strengthening the concepts), and a contrast of the existing with the new proposed paradigm is

[197] Termed in this paper as Paradigm Spermaticos as in Theological studies where the concept of Logos Spermaticos is used.

then created. Since this type of work is highly theoretical, examples (multiple explanatory applications) are presented to elucidate some of the possible implications of this hypothesis.

J.8 Kuhn on the nature of pre-paradigm as applicable to building construction.

"Pre-paradigm history is immensely circumstantial in detail that later become sources of important illuminations. Only very occasionally, as in the case of ancient static, dynamic, and geometrical optic, do facts collected with so little guidance from pre-established theory speak with sufficient clarity to permit the emergence of a first paradigm. However, if the body of belief is not already implicit in the collection of facts, it must be externally supplied perhaps by a current metaphysic, by another science, or by personal and historical accident."

"In the pre-paradigm period, paradigm articulation, are periods when scientific development is predominantly qualitative. In this stage the work is both with fact and with theory, and the work not only produces new information, but a more precise paradigm, obtained by the elimination of ambiguities that the original paradigm or theory from which they worked had retained."

"Pre-paradigm science seems rather a ramshackle structure with little coherence among its various parts. To be accepted as a paradigm, a theory must seem better than its competitors, but it not, and in fact never does, explain all the facts with which it can be confronted. Paradigm role as a vehicle for scientific theory functions by telling the scientist (researcher) about the entities that nature does and does not contain and about the ways in which those entities behave. This map is essential as an observation and experiment to science's continuing development by providing not only a map, but also some of the directions essential for map-making. In learning a paradigm the scientist acquires theory, methods, and standards together, usually in an inextricable mixture."

“If both ‘observation and conceptualization’, ‘fact and assimilation’ to theory are inseparably linked in discovery, then discovery is a process and must take time. In both cases the perception of anomaly, of a phenomenon, that is, for which a paradigm had not readied the investigator, plays an essential role in preparing the way for perception of novelty. But the perception that something had gone wrong is only a prelude to discovery.”

“Both during pre-paradigm periods and during the crises that lead to large-scale changes of paradigm, scientists (researchers) usually develop many speculative and unarticulated theories that can themselves point the way to discovery. Often, however, that discovery is not quite the one anticipated by the speculative and tentative hypothesis. Only as experiment and tentative theory are together articulated to match does the discovery emerge and the theory becomes a paradigm.”

The following are characteristics of discoveries that include: The previous awareness of anomaly, the gradual and simultaneous emergence of both observational and conceptual recognition, and the consequent change of paradigm categories and procedures often accompanied by resistance from the profession. Professionalization leads, on the one hand, to an immense restriction of the scientist’s vision and to a considerable resistance to paradigm change by professional rigidity. Novelty ordinarily emerges only for the person who, knowing *with precision* what he should expect is able to recognize that something has gone wrong. Anomaly appears only against the background provided by the paradigm. “Any attempt to date a “discovery” must inevitably be arbitrary because discovering a new sort of phenomenon is necessarily a complex event, one which involves recognizing both *that* something is and *what* it is.”

“The anomalies that lead to paradigm change will penetrate existing knowledge to the core! Overlap between invention and discovery is not identity. When the awareness of anomaly lasts long and penetrates deep, the scientific field can be affected by a state of growing crisis. Because of the possibility of large-scale paradigm destruction and major shifts in the problems and techniques of normal science, the emergence of new theories is generally preceded by a period of pronounced professional insecurity. Failure of existing rules is the prelude to a search for new ones."

"Philosophers of science have repeatedly demonstrated that more than one theoretical construction can always be placed upon a given collection of data. History of science indicates that, particularly in the early developmental stages of a new paradigm, it is not even very difficult to invent such alternates. But that invention of alternates is just what scientists seldom undertake except during pre-paradigm stage of their science's development and at very special occasions during its subsequent evolution. So long as the tools a paradigm supplies continue to prove capable of solving the problems it defines, science moves fastest and penetrates most deeply through confident employment of those tools. The reason is clear. As in manufacturing, so in science, retooling is an extravagance to be reserved for the occasion that demands it. The significance of crisis is the indication they provide that an occasion for retooling has arrived."

J.9 Philosophical underpinnings of an existing paradigm

"Perhaps the development of technology, like the development of science, should be viewed as proceeding within the framework of paradigms." It is in this context that Building Construction technology (theories and practice[198]) is approached in this study.

[198] Kuhn (2000): Technology continues to provide a two-way route between theories and reality, but reality provides the same sort of route between theory and technology, and theories provide a third route between reality and technology. Scientific practice requires all three of these sorts of mediation, and none of them has priority. Each of his three slices – technology, theory, and reality – is constitutive for the other two. And all three are required for the practice whose product is knowledge.

"A paradigm is at the start largely a promise of success. This promise of success is the actualization achieved by extending the knowledge of those facts that the paradigm displays as particularly revealing, by increasing the extent of the match between those facts and the paradigm predictions, and by further articulation of the paradigm itself". Determination of significant fact, matching of facts and theory, and articulation of theory display the following characteristics:

1) In a pre-paradigm or at a time of crisis, such as when shifting between paradigms – revolution - there is no-body-of-theory. Because of the possibility of large-scale paradigm destruction and major shifts in the problems and techniques of normal science, the emergence of new theories is generally preceded by a period of pronounced professional insecurity. Failure of existing rules is the prelude to a search for new ones. The following statements from Koskela et al. are applicable:

    a. Construction productivity lags behind that of manufacturing
    b. A lack of a theoretical foundation in construction
    c. Well known problems of construction, causal relation of such disappointments can not be established definitively
    d. Structural changes are needed to the organizational pattern and or the flow of information and materials
    e. Need to develop further the theoretical foundations or first principles, of production in general and especially in construction, chronic performance problems can more or less directly be associated to problems of theory
    f. 'During the next decade, the formation of a theory of construction will be the single most important force influencing the construction industry'
    g. Lack of explicit theory
    h. Inherent variability in production degenerates into mutual adjustments by the team on site

i. Scope of change is needed, the big foundational ideas of change, as well as the initiation of change and keeping its momentum.

j. 'We have not gone far enough in seeking a basic framework for the construction of facilities'

k. "Industrial history indicates that improvements in the range required in construction happen only when the whole production template is changed". This production template change is based on NEW BIG ideas, NEW THEORIES

l. Koskela et al argue for starting at the end because firstly this is where cost, time, quality, etc… are concretely formed and secondly because what we learn can be taken upstream.

m. Renewal initiatives such as industrialization, open building, design-build, partnering, re-engineering, Just in Time, Lean Construction

n. Theory of production (incorporating the afore-mentioned concept of transformation, flow and value –T, F & V) and a theory of management and conceptualization (design, operations and production system improvements) and a theory of the peculiarities of construction

o. Presuming that construction is a fragmented[199] and fluid industry that can not be changed overnight

p. A wider and more powerful theoretical foundation is needed.

q. What is needed is a production theory and related project management theory that fully integrate the transformation, value and flow concepts.

r. Without an underlying theory, it is almost impossible to have access to the deficient assumptions or argue about methodology

s. Based on new theories on operations management, new project management methods may be developed and tried out and (2) advance practice may be consolidated and explained theoretically.

t. Prevalent theory of construction which is implicit, deficient, and is a hindrance to innovation

u. Methods of other templates, such as manufacturing and re-create them in a construction environment. But the core ideas or concepts of the organization innovation must be abstracted and re-created in an application that fits local conations.

[199] Dubois and Grade, 2002; Groák, 1994: "Construction can not be considered a coherent industry with definable boundaries and characteristic problems."

v. Trade (the craft mentality) the authors state, has no incentive to share learning experiences for the sake of re-applying them in future projects by a differing crew for the sole benefit of the general contractor.

w. It is concluded that the peculiarities should be resolved when they are not needed. However, before a decision is made, the additional costs or even the potential value loss that may be caused by peculiarities must always be related to whole life costs and value of the object built, and the extra costs and efforts for resolving the peculiarities.

2) In such cases, especially in time of crisis, Kuhn observed, there is so much research in all directions with little benefit but with increasing complexity. When complexity increases far more rapidly than its accuracy or benefit and that a discrepancy corrected in one place is likely to show up in another may lead to a similar proclamation as that of Alfonso X, that if God had consulted him when creating the universe, he would have received good advice, or Copernicus comment in *De Revolutionibus* that the astronomical tradition he inherited had finally created only a monster. "Proliferation of versions of theories is a very usual symptom (or concomitant) of crisis." The Construction 'Industry' trends and initiatives are deemed to fit this 'proliferation of theories and practices' observation, like parts of a puzzle trying to fill- in the gaps of perceived deficiencies in the system that have appeared only because of the background provided by the reigning paradigm such as the following:

- ***Organization related:***
  - *Project Management (Miozzo and Ivory, 2000);*
  - *Partnering (Baden, 1995; Barlow et al., 1997; Bennett and Jayes, 1998; Conley and Gregory, 1999; Cowan, et. al., 1992; Larson, 1995; Matthews, 1996a; Matthews et. al. 1996b; Slaughter, 1998; Barlow et al. 1997; Godfrey, K., A., 1996; Rackman et al. 1996);*
  - *Project Definition Rating Index, (PDRI™) (Durmont, et. al., 1997; Cho, et. al. 1999);*
  - *Learning Organizations (Edmondson and Moingeon, 1998);*
  - *Knowledge Management (COM, 2000);*
  - *Open Building (Kendall and Teicher, 2000; Van der Werf, 1990)*
  - *Virtual Organization (Winch, 1989).*

- ***Performance related:***
  - *Total Building Commissioning (USGSA, 1998; NIBS 1999);*
  - *Lean Construction (Alarcon, 1997; Ballard and Howell, 1998; Santos, 1999; Howell, and Koskela, 2000; Vrijhoef, R., Koskela, L., Howell, G., 2001; Ballard et al. 2002; Koskela et al. 2002; Vrijhoef et al. 2002);*
  - *Concurrent Engineering and Fast Tracking (Ballard, G., 1999)**;***
  - *Just in Time Production (JIT) (Gilbreths and Gilbreth, 1922; Hopp and Spearman, 1996)**;***
  - *Total Quality Management (Shewhart, W., A., 1931)**;***
  - *Continuous Improvement Theories (Wortmann et al. 1997**);***
  - *Theories of Integration (Wortmann, J.C., 1992)**;***
  - *Robotics (Sangrey and Warszawski 1985; Warszawski 1990);*
  - *Re-Engineering (Rockart and Short, 1989; Hammer, 1990; Davenport and Short, 1990; Hammer and Campy, 1993; Betts and Wood-Harper, 1994; Mumford and Hendrix, 1997; Winch, 2003);*
  - *Last Planner (Ballard, 2000);*
  - *Constructability and buildability (Ferguson 1989; O'Connor 1986; Shin 1992)*
  - *Value Engineering and Management*
  - *Life Cycle Costing*
  - *Critical Path Scheduling*

- ***IT related:***
  - *^{n}D CAD - parametric oriented, web based real time multi-user platforms (FIATECH, 2004; Koskela and Kazi, 2003; Fenves, 1996;* Johnson, R. B., 1995*),*
  - *Digital Building Process and As-built Documents (Winograd and Flores 1986; Tabatabai-Gargari and Elzarka 1998).*

- ***Codes and Standards related:***
  - *Performance Base Building Codes, Standards and Specifications.*

- ***Contract and Structure related:***
  - *Integrated Project Delivery Systems (such as: Design-Build and similar variations (Bowley, 1966; Konchar and Sanvido, 1998; Bennet et al. 1996; Lahdenperä, 2001),*
  - *Construction Management @ Risk and multiple variations);*
  - *Subcontractors and Vendors Alliances (Cox, A., and Townsend, M., 1998;* Pyke, 2002*).*

- ***Environmentally related:***
  - *LEED® (US Green Building Council)*
  - *BREAM™*
  - *GBTool™ (UK)*
  - *BASIX (Australian)*
  - *HQE^2R (CSTB - France)*

- ***Facilities Management:***
    - *Energy Star™*
    - *Benchmarking*
    - *Continual Commissioning*

The puzzle always exists only because no paradigm that provides the basis for scientific research ever completely resolves all its problems. Every problem that normal science sees as a puzzle can be seen from another viewpoint, as a counter-instance and thus as a source of crisis. However, even the existence of crisis does not by itself transform a puzzle into counter-instance. Crisis loosens the rules of normal puzzle-solving in ways that ultimately permit a new paradigm to emerge.

Normal science does and must continually strive to bring theory and fact into closer agreement, and that activity can easily be seen as testing or as a search for confirmation or falsification. Instead its object is to solve the puzzle for whose very existence is the validity of the paradigm can be assumed. When an anomaly comes to seem more than just another puzzle of normal science, the transition to crisis and to extraordinary science has begun. The anomaly itself now comes to be more generally recognized as such by the profession. More and more attention is devoted to it by more of the field's most eminent scientists. If it still continues to resist, as it usually does not, many of them may come to view its resolution as *the* subject matter of their discipline, a new fixation point of scientific scrutiny.

An even more important source of change is the divergent nature of the numerous partial solutions that concerted attention to the problem has made available. The early attacks upon the resistant problem will have followed the paradigm rules quite closely. But with continuing resistance, more and more of the attacks upon it will have involved some minor or not so minor articulation of the paradigm, no two of them quite alike, each partially successful, but non sufficiently so to be accepted as paradigm by the group.

For example, current efforts at Lean Construction have been praised as a new paradigm (Ballard and Howell 2004). However Lean Construction is more like one of the many pieces of the puzzle in the background of the reigning paradigm, which has not been identified!

3) In pre-paradigm and crisis, quantitative wording does not function unequivocally. Fuzziness at the borders is expected and it is the acceptance of fuzziness that permits drift, the gradual warping of the meanings over time. In the sciences, borderline cases of this sort are sources of crisis and drift is correspondingly inhibited, requiring special precision in reference determination. History of science indicates that, particularly in the early developmental stages of a new paradigm, it is not even very difficult to invent such alternates. But that invention of alternates is just what scientists seldom undertake except during pre-paradigm stage of their science's development and at very special occasions during its subsequent evolution. The early developmental stages (pre-paradigm) have been characterized by continual competition between a number of distinctive views, each partially derived from, and all roughly compatible with, the dictates of scientific observation and methods.

- Plan production to be essentially synonymous with action.
- Ballard and Howell (2004) acknowledges that in construction management there is a 'talking through each other' and claims that is due to competing paradigms[200] namely Traditional vs. Lean Construction.
  - Project: Different conceptualizations of a project: (1) Delivery in conformance to a contract and (2) Lean Construction: Need to minimize waste and maximize value
  - Management: (1) Management-by-Results with financial targets and performance against those targets – goal setting before the act of production and (2) Management-by-Means (Lean Construction) – production system design before, systems operations during and improvement after the act of production.

[200] Ballard and Howell 2004 concept of exiting paradigm is termed, as Traditional, but it is not elaborated as to where it comes from what are the basic core concepts and how has it evolved through history.

- Control: (1) After the fact variance detection and (2) Lean Construction: control as active steering of a production system or project towards its objectives.

4) Kuhn’s (1962, 1976) central terms in *The Structure of Scientific Revolutions* acquired a significant part of their determinate content from multiple explanatory applications, and thus an acceptable methodological approach that will be presented at the end of this Part II. Verification, if you please, is achieved by the fact that the several explanatory applications mutually constrain one another (via the theory) thereby avoiding circularity and are exemplary because they emphasize learnable and transferable skills.

5) As in manufacturing so in science – retooling is an extravagance to be reserved for the occasion that demands it. The significance of the presence of crisis is the indication it provides that an occasion for retooling has arrived.

APPENDIX K

DEVELOPMENT OF SUSTAINBLE CONCEPTS

Sustainable development (Midgley and Reynolds 2004; Nooteborn and Teisman 2003) thinking started in earnest in the 1980's with a rudimentary set of generic guidelines offering no more than sign posts in the transition of contemporary socio-economic systems towards a more sustainable development path (Midgley and Reynolds 2004; Turner 2006; Nooteborn and Teisman 2003). Briefly these guidelines called for the following:

- Correction of existing market failures where overexploitation of resources occurs because:
    - Goods and services are incorrectly priced
    - Policy intervention failures
- Measures to ensure the regenerative capacity of renewable resources
- Avoidance of cumulative pollution
- Recognition of the need to steer technological innovation and application towards more eco-efficient processes
- Precautionary approach to development, given the inevitable uncertainty about the impact of human society on its supporting environment
- A warning on unsustainable human activity due to lifestyle choice and patterns of consumption (wants rather than needs)

Von Weiszäcker et al. 1997, have proposed a doubling of wealth by halving resources (Factor 4), and Schmidt-Bleek (quoted by Kibert 2005) to a Factor 10, reducing consumption by a factor of 10, such as the guidelines adopted by the European Union, but with no successful examples of implementation. This Factor 10 proposes the reduction (i.e. reducing commercial building energy use from the current average of 100,000 to less than 10,000 BTU / square feet.)

Sustainability in construction was further refined through programs such as LEED where metrics are applied on a rational basis. Other programs articulating metrics for sustainability are: U.S. Army SPiRit program and the US Government Energy STAR programs. A model was developed by Forrester (1971), and improved by Sterman (2002), for gauging global impacts.

Mathematical constructs were refined by Chichilnisky (1997) in what is termed the 'turnpike effect". CIB 2000 (quoted in Kibert 2005) articulated seven principles of sustainable construction:

- Reduce resource consumption (reduce)
- Reuse resources (reuse)
- Use recyclable resources (recycle)
- Protect nature (protect)
- Eliminate toxics (eliminate)
- Apply life-cycle costing (economics)
- Focus on quality (quality)

In England, the Pearce Report (2003) looked at sustainability and construction in particular from an economic viewpoint and created an integrated strategy of practical trade-off situations. The report added transparency to the long term objectives based on a definition of sustainability as "improving value over time[201]" (Kohler 2006). The report acknowledged that the concept of sustainability is difficult to operationalize in a decision support system that includes methods and techniques capable of measuring sustainable development (or lack of it, Midgley and Reynolds 2004; Nooteborn and Teisman 2003).

Pearce and flowers preferred a total factor approach based on micro-studies rather than on sectors or entire industries. However, they acknowledged that a problem exists regarding data and that the first step is to define the desired data. The Pearce Report is a major conceptual framework for relating different dimensions of value, four forms of capital (ecological or natural, economic or man-made, social or cultural, and innovation-productivity or human) and how these dimensions interact over time and the possibilities and limitations of substituting one capital for another, the 'capital theory' approach. Sustainability requires a non-declining capital stock over

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[201] Pearce 2006 states that economists have a long tradition of generally agreeing on the generation of human well-being, or welfare, or, an old-fashioned term utility as the goal of any society. "What needs to be sustained is this

time to be consistent with the criterion of fairness across generations (Pearce et al. 1989; Pearce and Turner 1990; Pearce 2003).

The Pearce Report is an economic accounting of sustainability based on a socio-economic value of construction. It does not provide a full description of either, but lays down a framework for both and provides a basis for establishing sustainability indicators for construction (also see Bell and Morse 2004). Borrowing from other disciplines the report introduces to construction industry analysis a number of different approaches to measurement on capital and establishes the possibility of linking these aspects together.

The results from the Pearce Report (2003) and followers are:

- Sustainability as "improving value over time" requires a rising per-capita endowments of the four capitals (natural, artificial, social and human)
- An overall accounting needs to consider the value of changes in total wealth through net investments and natural capital (the environment, and its conservation over intergenerational time)
- Sustainable goods and services should meet people's needs rather than wants (Neumayer 2003)
- The simultaneous use of less natural resources and waste production
- The use of land, such as in Ecological footprinting techniques, rather than money, as the unit of accounting (land area is attributed to the consumer rather than the producer)
- Increasing resource efficiency by reducing materials and energy wastage at all stages of production (estimated at a factor of 4 to 10) through incentives such as environmental regulation, taxation and charging reforms (through regulatory framework in terms of this dissertation)
    - The use of economic incentive mechanisms
    - The elimination of perverse subsidies
    - Landfill disposal charges
    - Congestion charging
    - Carbon emissions trading (now a reality)
- Fewer rucksack (the sum of all the materials necessary for production, use, recycling and disposal of the goods) by weight reduction through reduced material flow, generally

well-being." In terms of human needs, then according to Pearce, is the capability to generate well-being. Humans are considered to be in themselves a capital asset, thus 'human capital'.

- The process is about small independent changes such as depleting a forest here and emitting harmful emissions there. Reduction of one capital asset is not consistent with sustainability unless another asset is increased
- Savings must exceed depreciation of assets and accumulated wealth must proceed at a rate faster than population growth
- In the end, it may be a good thing that some industries decline, therefore great care must be taken in determining sustainability at the level of an industry by
    - Some measure of sectorial savings
    - Data on the depreciation of assets (to determine responsibility)
    - Other assets need to be accounted as well (i.e. skills, human knowledge, design etc)
    - The tricky issues of where the money values come from needs to be addressed

The Pearce concept of multiple types of capital is extended in this dissertation by identifying and analyzing the different disciplines that historically have affected construction. Unlike accounting, where a balance is sought between assets and liabilities, the dissertation uses a vectorial approach to measurement complex systems, linking these aspects together and relating them to the exponentialoid growth in question. The balance is between the elements of influence and the exponentialoid. Vectorials are used to capture a higher degree of complexity in the elements of influence and their interaction both from the observed exponentialoids and for the taming of those exponentialoids. Building construction, if it is to fully contribute to taming the exponentialoids needs to heed the elements that influence its change in their full complexity.

APPENDIX L

OBSERVATIONS ON CONSTRUCTION AS AN INDUSTRY

Appendix K is the result of venturing into the economic view of construction and sustainability using the popular terminology, concept and use of the term construction 'industry' and sometimes referring it in economic parlance as a 'sector'. However both 'industry' and 'sector' are deficient symbols and fail to encapsulate the meaning of the reality behind 'construction' or even the more discrete 'building construction.'

Carassus, 2004 from CSTB states on CIB publication 293, The Construction Sector System Approach: An International Framework, in regards to the notion of the economic sector system applied to construction that:

> "Mesoeconomic literature offers several possible unifying notions: sector, production chain, economic meso or sector system, industry cluster. The notion of sector, defined as an economic sub-group uniting firms with the same core business, is very useful but too limited in relation to a research subject dealing with the entire system set up to solve a complex productive issues."

The notion of the production chain, defined as a series of successive production stages linked by commercial exchange fluxes where production technology plays an essential part (Morvan, 1991) is likewise centered too exclusively on production. However the notion of the economic meso or sector system (hence system of systems), according to Carassus (2004) is the most adequate if defined "as a complex system of organized commercial or non-commercial relations between participants, having the capacity to solve a productive issue relating to a type of goods or services."

This dissertation uses the US governmental classification system (previously noted in a footnote):

Under the NAICS (North American Industry Classification System), the

> construction industry is listed in the service sector of the economy under section 23 and is broken down into many categories, such as Buildings (236) and Heavy and Civil (237). Construction is considered a basic industry like others such as manufacturing, mining, fishing and farming (www.census.gov).

However, in literature and in common parlance Construction, Building Construction is referred to as an 'industry'. Epistemologically, the concept of 'industry' affects the way we use the symbol 'industry' and the meaning attached to it. This has significant implications to the way we conduct research, our mental constructs, our paradigm, worldview and our expectations.

Construction at a firm level (micro level) has moved from being a single source provider to a service provider, the sense of construction in general and building construction in particular that is adopted by the macro concept of the macro-aggregates, total economy, and the 'general economy.'

The dissertation is concerned with the implications behind the concepts 'industry' and 'sector' which do not capture the nature of building construction. We suggest that the new and untested concept of meta-industry (as in meta-systems) as in industry of industries or sector of sectors if you will, along with the characteristics posed in Dr. Palmer's second PhD dissertation as closer to the reality of construction. However, how can we test that building construction acts like a meta-system based on the current theoretical foundations could be a fertile subject for future post-graduate work.

The dissertation promotes the concept of the Construction Industry as an "industry of industries" in other words a "meta-industry". However because the concept of a meta-systems (thus meta-industries) is at a proto-theoretical (some may call it philosophical) stage where the relationships and characteristics of a meta-system have not been proven, the dissertation does not advances a novel and firm definition of the "Construction Industry."

This dissertation advances, in its pre-paradigmatic approach, a look at the state-of-the-art research, albeit proto-theoretical and un-proven, for ideas and concepts that appear to have the potential to become contributors to a novel worldview, one that ultimately appeal to like-minded researchers for further definition such as the industry of industries, a meta-industry concept as it is currently being crafted. Obviously this concept by itself will undergo criticism and evolution on its way of moving from philosophical logic, to theory, hypothesis, testing, verification and argumentation.

Carassus 2004 proposed:

> "The construction economic sector system can be defined as *the organized complex of commercial and non-commercial relationships, between productive and institutional actors, taking part in the production and the management of services provided by the structures used, throughout their life cycle, as the living and working environment of a population."*

Definitions of construction such as this fail to take into consideration the high degree of fragmentation, individuation, self-organization, autonomy, the holes between sectors and industries where the capacity for change and innovation resides (the orders for construction products present an extraordinary diversity and heterogeneity) as well as its dysfunctional characteristics, as noted in our dissertation.

Personally I apologize if the dissertation conveys a subjective understanding of the construction industry as dysfunctional in a pejorative sense. The so call industry functions 'as it is.' Apologetically speaking, construction, including building construction has satisfied human needs and wants through millennia, in an atmosphere of diverse cultures, civilizations, drastically different socio-political-economic and even impervious to incompatible religious system.

Sometimes the criticism of the industry as inefficient and dysfunctional may have ulterior motives such as to create a platform that justifies a plethora of technologies or processes promoting a panacea to the alluded inefficiencies. Personally speaking again, it may be that the current systems (product of the processes and technologies developed in the framework of the current industrial revolution) are at the point of diminishing returns and are awaiting the next quantum leap in technology that will require totally new processes and technologies, a new mindset that works in an evolved or radically new paradigm.

For example scientist now believe that at the macro level as well as at the micro level of nano realities, current paradigms in all areas, including all insights and laws of science do not apply. A whole new set of laws, languages, symbols and meanings have to be developed to be able to understand their own realities that are not translatable to those in the middle of this spectrum. This will require new worldviews, new paradigms but above all and firstly new languages that are able to capture the revealed and perceived nature of these realities. This is not to far off from what needs to be done in sequel to this dissertation: finding a new language that captures the realties of complex forces that at this point in time appear to have some kind of vectorial nature that in a meta-systemic framework can accept presence of inefficiency fragmentation as a positive characteristic for evolution, adaptation, growth.

The current interpretation of the industry has having a high degree of inefficiency, fragmentation (Carassus 1998), is an indicator of a meta-system, full of holes - inefficiencies where precisely opportunity resides. Inefficiency, differentiated fragmentation is balanced by a high degree of opportunity for innovation and creativity, albeit not used (a 'traditional' industry set with true and proven ways means and methods, comfortable with the past, the inertia that existing paradigms exert). Perhaps once the challenges are identified and a crisis threshold is approached, the industry will step up to the plate, beginning with a different set of owner performance requirements promoting a solution to a much more critical global problem, one based primarily on sustainability and performance and secondarily on cost, and schedule.

The observation that the newcomer, sustainability, could attain primacy over cost and schedule is due precisely because the industry is dysfunctional, has excess unused capacity that is currently perceived in relation to, and benchmarked with other more focused and apparently more efficient industries.

However all the industries are contributors to the present dilemma and a race for a solution to the exponentialoid problem, again in our view, is not dependent on efficiencies of the current Industrial Revolution based on chemistry and the atom but on a new paradigm, a new revolution based on a radical technology, such as nano-tech, albeit with new, unidentified and possibly even more harmful and/or more benign effects.

What rules is the identified philosophical principle that we have no option but to address technological problems with more technology, unless we capitulate on Ellul's wage of the century.

APPENDIX M

ADDITIONAL OBSERVATIONS ON HOW CHINA IMPACTS THE WORLD

(Excerpts from Kynge 2006, China Shakes the World and The Stern Review Report)

Two additional and highly relevant information sources have been published since the dissertation defense that took place October 6, 2006: Both Kynge's book and The Stern Review Report were published in the middle of October. Both releases contain material that supports the premises that identify the forces driving not only the General Economy at a Global scale, but in specific building construction resource consumption and emissions generation.

Kynge's book is the equivalent of HUMIT or human intelligence from the field. Kynge is the former China bureau chief of Financial Times in Beijing with an Asia presence of twenty years, fluent mandarin and has visited every Chinese province.

The Stern Review Report is the most up to date scientific and research oriented exposition and analysis of Environmental related issues, a milestone of human knowledge intended to marshal the necessary forces to tame an exponentialoid growth, even though they do not approach the subject in this manner.

The following are excerpts of the most relevant issues from both reports:

M.1 Kynge, 2006 China Shakes the World

China's economy has been growing at an average of more than 9.5 percent annually for the past twenty-eight years, except that in 1995 it grew more than 14%. During this period, more than four hundred million people have been lifted above the poverty line into middle class consumption. "Never before, has so large a country emerged so rapidly from so eviscerated an environment base."

A brief history of this rapid change starts in an isolated economy during the Communist era of Mao with an increasing population of close to a Billion and 30 million starving in 1960. Deng, the next Chairman gambled on making major industrial purchases to be funded by the discovery of big new oil deposits that did not materialized. To prevent the situation from getting worse Chen, an economic advisor, convinced the ruler to allow farmers to plant and directly reap the harvest of their labors. By 1984 the national grain harvest had risen to 448 million tons from 335 in 1978 and meat became more widely available. Creative disobedience ensued in other parts of the economy with stories of rags to riches with risk and hardship as common denominator.

The agricultural kicking point, the early tinkering with furnaces and machinery, the importing of discarded, scrap or obsolete equipment and refurbishing them back to production parallels the start of the Industrial Revolution in several countries. The difference is the scale and speed of the revolution. Chongqing is compared to Chicago, the "city of the century" in the nineteenth Century. Chicago took fifty years until 1900 to increase its population by 1.7 million people while Chongqing is growing at eight times that speed. In the six years, beginning in 1998, it grew 1.7 million, or an average of nearly 300,000 new inhabitants a year.

In 1949 the number of Chinese cities with a population of more than a million was only five, and those with between 500,000 and a1 million inhabitants numbered eight. In the year 2000, the numbers have risen to forty and fifty three respectively. "The investment required to settle so many people in an urban environment is impossible to calculate with any accuracy, but it is clear that worldwide demand for steel, aluminum, copper, nickel, iron ore, oil, gas, coal and many other basic materials and resources may remain strong for as long as cities in China expand at a rapid clip."

The reason for this growth is that 700 million form a pool of people that are thought to get by with less than two dollars a day. "This provides a huge pool of labor that is willing to work at pre-industrial wages in factories capable of producing goods at a speed that is many times faster than was possible during the Industrial Revolution in England some 230 years ago… The marriage of cheap labor and modern factories does much to make China competitive, and the competitiveness justifies the huge investments required to carry forward the expansion of cities."

The lines of expansion are deep: Beijing plans by 2030 or sooner, to have laid 53,000 miles of road networks (about 10,000 more than exists in the USA), along with rapid trains, cargo trains, improved port facilities, airports and airplanes, trucks and terminals. "Each year since 2004, China has installed the equivalent of all the generating capacity of a country such as Spain, and it is expected to continue repeating that feat in years to come." From almost no significant automobile presence in the 1960's to 60 million in 2005 and 160 million minimum predicted by 2010, China is the fastest growing auto market in the world. By the year 2008, the FT 11/6/06 reports that China will consume more iron ore than the rest of the world together.

Ageing is also a concern, "by 2040, around one-third of the projected population – some four hundred million people – will be over the age of sixty. It may be that China will grow old before it becomes rich." Employment is also a concern: "Even when the economy grows at 9 or 10 percent, it fails by a margin of several million to create the twenty four million new jobs required each year. So while China appears to the rest of the world to be enjoying an amazing growth bonanza, the official working behind the high walls of their leadership compound in Beijing feel trapped in an endless employment crisis."

The approach to local consumption and exports by China is the opposite to that of Japan. Once an item begins successful and profitable mass production in China the local market becomes saturated with producers driving down the local margins and saturating the local demand for the product. Japanese companies are known for financing their forays into export markets by charging more for their products at home than they do abroad. Chinese corporations do just the opposite; many export as a means of staying afloat at home.

Kynge observes that "throughout history, the big shifts in the global power balance and in the hierarchy of nations have all been accompanied – or, often, preceded – by a whole set of new price signals. China exporting deflation in manufactured products is an early signal of a shift in the distribution of geopolitical power.

China is climbing the technological ladder at a rapid pace and its ascent is neither localized nor specialized, but identifiable almost across the board. The difference between China and previous developing countries technological climb is that China's is driven not so much by research as by commerce: Buying, copying, encouraging transfer and through any other conceivable acquisition means. According to Paul Krugman, a US Economist, (Kynge 2006) an access to technology driven by "perspiration than inspiration."

Service jobs are also at risk, according to the McKinsey Global Institute. The number of service jobs moving to China and India could eclipse those that moved from manufacturing. Outsourcing from the USA alone could top 9.6 million jobs (that would shift our current 4.4% unemployment to 11.4%, and other parts of the world will have similar or even more pronounced service job attrition.

Chapter 6, "Not enough to go around: natural resources and environmental catastrophe" is a confirmation of the premises of the dissertation and should be read in its entirety. The environmental degradation in China at the present time eclipses that of the Soviet Union in its worst apocalyptic scenario and is getting worse. Meanwhile, hundreds of millions of Chinese have begun to seek a new life, and many of the things they demand – fuel, metals, food, materials, and a certain quality of life – are simply not available in sufficient quantities within the boundaries of their environmentally exhausted nation. "China can drive down, through labor, the average level of working wages and the prices of manufactured products worldwide, while propelling the prices of most sources of energy and commodities through the roof. The cleavage between these areas of influence falls neatly between the things China makes and the things it needs." Human rights in China have been redefined as "…having guaranteed access to energy. It means having petroleum to run your car." "If the Chinese were ever to consume at the American (oil) levels of 2001, they would need to guzzle three times the world's total consumption." Another FT 11/8/06 report on Aluminum states that in 1996 China produced 1.5 m tones compared with the USA (number one place) production of 3.6 m tones. In 2006, China is expected to produce 9.3 m tones compared with the USA 2.3 m tones (slipping to fourth place).

A new era in international relations dawned, one defined by the geopolitics of scarcity. As recently as five years ago, Beijing's leaders hardly had to worry about where and how their companies would secure supplies of oil, gas, and a host of traded commodities and resources. In those days, the nation's demand, though significant, was relatively easily accommodated on world markets. But now China is the second-largest importer of oil in the world after the United States. Its imports of aluminum, nickel, copper, and iron ore have risen from an average 7 percent of world demand in 1990 to a predicted 40% by 2010. As a result, Beijing has become anxious in case supplies of crucial resources run out or are diverted to other countries, threatening the growth that produces the twenty-four million new jobs it must create every year. Thus scarcity, or finding ways to alleviate it, has in a few short years leapfrogged up Beijing's agenda to become the key motivator of foreign and domestic policies. Kynge observes that "although trade increases the mutual economic dependence of the countries that engage in it, trade does not make the peoples of those nations any fonder of each other."

M.2 The Stern Review Report

The Stern Review Report widens the debate on the environment by examining the economic ramifications that different scenarios present. The report claims that climate change could shrink the global economy by about 20% and that taking action now would cost 1% of global domestic growth. According to Tony Blair, British Prime Minister, the consequences of global warming could be "disastrous" and inaction is not an option.

The findings of The Stern Review Report are substantiated by the also recent World Meteorological Organization publication Nov. 3, 2006 that the 2005 greenhouse carbon dioxide concentration had increased by 2% a year for the past decade. "To really make CO2 concentration level off, we will need more drastic measures than are in the Kyoto protocol today," said Geir Braathen, senior scientific officer at WMO quoted by FT 11/4/06.

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