TAKING THE STAIRS: ENVIRONMENTAL FEATURES THAT PREDICT STAIR USE IN 3 TO 4 STORY ACADEMIC WORKPLACE BUILDINGS

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This dissertation is dedicated to
to your health and well-being

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LIST OF ABREVIATIONS

Adj. R^2	Adjusted R squared
Avg.	Average
BOCA	Building Officials and Code Administrators International
Caltrans	California Department of Transportation
CPTED	Crime Prevention Through Environmental Design
C. Total	Count total
DF	Degrees of freedom
Ft.	Feet (metric dimension)
Ftc.	Footcandles (illumination)
GTCOA	Georgia Institute of Technology College of Architecture
GTEL	Georgia Institute of Technology Erskine Love Manufacturing Building
GTIBB	Georgia Institute of Technology Parker H. Petit Biotechnology Building
GTMARC	Georgia Institute of Technology Manufacturing Research Center
GTUAW	Georgia Institute of Technology U. A. Whitaker Building
MET	Metabolic equivalent, 1 MET = the energy used by the body at rest
MIP	Most Integrated Path
n	Sum weight of observations
OBC	Ontario Building Code
RYARSC	Ryerson University Architecture Building
RYENG	Ryerson University Centre for Engineering and Computing
RYGCM	Ryerson University School of Graphic Communications Management
RYINT	Ryerson University School of Interior Design
RYMON	Ryerson University Monetary Times Building
Sec.	Seconds (time)
Sq. ft.	Squared feet (area)
Std. Dev.	Standard deviation
Standard Dev.	Standard deviation
Std. Err. Mean	Standard error mean
Wgts.	Weights
%	Percentage

SUMMARY

Although increasing stair use among adults with sedentary occupations can provide an accessible means of integrating moderate physical activity within daily work routines, there is little evidence-based information available to guide architects on how to design buildings that promote stair use. This study examined the relationship between stair use and a broad range of features of the physical environment within 10 buildings. Based on review of the literature, a thematic framework (Appeal, Convenience, Comfort, Legibility and Safety) was developed for identifying the features of buildings that may influence stair use.

Several methods of investigation were used to examine the relationship between stair use and variables of the five themes and their constructs.

1) Buildings users were surveyed for their reasons for both single and multi-level route choice. The results indicated that reasons associated with convenience and legibility of route had greater influence on route choice than appeal, comfort or safety.
2) Stair and elevator use were measured in the ten buildings along with variables that operationalized the thematic framework. Stair use was determined by the percent of total vertical travel measured on the most-used flight (in most cases ground to second floor) by active infrared monitors.

Regression analysis was utilized to examine the relationship between stair use and operationalized variables of the thematic framework. The results of regression analysis indicated that stair use was associated with 8 key spatial variables of convenience and legibility (travel distances from stair to nearest entrance and to the elevator, percentage of total building area or total occupant load attributed to each stair, physical accessibility of each stair, area of stair isovist, number of turns from the stair to closest entrance and to the most integrated path). Most local environmental features of stairs such as lighting levels and views were not statistically significant.

Multivariate analysis indicated that three variables (effective area of each stair, area of stair isovist, and number of turns required between the stair and the most integrated path) explained 53% of stair use.

3) A graphic analysis of the arrangement of the 8 key spatial variables within the ten buildings indicated that buildings with high overall levels of stair use optimized the key spatial variables in respect to the location of stair(s) within the building floor plan The study identified two sets of strategies from buildings with high stair use (over 60% vertical circulation in the building by stairs):high stair use predominately from one well-used stair in the building, and high stair use in the building from the use of several stairs in the building. The strategies are differentiated by the number and location of stairs located

along the most integrated path(s) (a space syntax measure)that links the building principal entrances.

The findings of these studies suggest that stair use is principally predicted by the eight key spatial variables that facilitate the convenience and legibility of stairs along the most integrated paths of travel linking building entrances. Based on this study, the follow basic design recommendations can be made:

- Locate stairs directly along the main paths of circulation, at or linking the principal entrance(s) to the building. Locate stairs between the entrance and the elevator such that the stairs are closer and initially more visible than the elevator from the entrance.
- Locate stairs so that their point of entry (door or first step) is visible from the elevator
- Locate stairs so they are in close proximity and highly visible to where people are located with in the building. Locate stairs between the spaces where people work, congregate and/or travel and the elevator.
- Orient the stair so it is visible from the largest area where people travel. Locate stairs so it is more visible than the elevator from the main entry and from multiple directions of travel along the main paths of circulation in the building.
- Orient the entrance doors to the stair and/or the first step of an open stair so that it requires the fewest turns in direction to enter the stair from the entrance and the main paths of circulation in the building.

- Provide sufficient stair width to accommodate people traveling by stairs in groups for the multiple types of activities that occur in the building including social engagement, high occupancy movement and emergency exiting.
- When possible maintain accessibility between floors at all levels Locate stairs within the public area of the building.
- Increase the visibility of a stair by providing open stairs such as grand stairs, open non-grand stairs between floors (when an interconnected floor space is permitted by code), electronic hold-open devices on doors of enclosed stairs, and/or fire-rated glass partitions (when a fire separation is required by code).

This study contributes to our understanding of stair use and the built environment. Although the study does not link stair use directly with health benefits, it provides a foundation for the development of spatial design guidelines and typologies for buildings that encourage stair use, which may benefit the health of the millions of Americans within office workplace buildings.

CHAPTER ONE:
INTRODUCTION

1.1 Principle Aims

Stair use can provide an accessible means of integrating moderate physical activity within daily work routines. Several studies have examined how interventions such as motivational signs and enhancing the level of interior finishes may increase stair use in existing stairs (Blamey & Mutrie, 1995; Anderson, Franckowiak et al. 1998; Andersen, Franckowiak et al. 1999; Kerr, Eves et al. 2000; Coleman & Gonzalez, 2001; Kerr, Eves et al. 2001; Marshall, Bauman et al. 2002: CDC, 2002; Kerr, Yore et al. 2004). While these studies generally found increases to baseline values due to the interventions, the increases were generally modest when compared to the variability in baseline values across the set of studies. This opens the question of what predicts this variability. This study aims at understanding the role the physical environment plays in the variability in stair use in buildings, especially workplace buildings, and what potential architectural design may have in encouraging stair use

1.2 Stair Use and Health Benefit

Americans are experiencing an epidemic of chronic health issues related to workplace and lifestyle behaviors including inactivity which contributes to some 200,000 unnecessary deaths per year due to stroke, cancer, obesity and diabetes (USDHHS, 1996; Kahn, Ramsey et al., 2002; Jones, Macera et al., 2003; CDC, 2001). Medical research studies have demonstrated that physical activity can provide beneficial health outcomes by reducing the risk for the three major causes of death for Americans: cardiovascular disease (Powell, 1987), adult onset (Type 2) diabetes (USDHHS, 1996) and cancers such as colon and breast cancer (Powell & Paffenbarger, 1985). There is also evidence that physical activity helps in the prevention and management of other chronic diseases by improving mental health, and preventing the development of osteoporosis (Kirkwood, Culham et al., 1999).

The 1996 United States Surgeon General Report on Physical Activity and Health recommends that people engage in a minimum of 30 minutes of moderate intensity physical activity on five or more day per week. Moderate intensity physical activity is quantified as an activity that expends 3 to 6 metabolic equivalents (METs) or three times the energy expended while sitting quietly. For example, brisk walking is considered a moderate intensity physical activity. Stair use is also a moderate intensity physical activity although it can also be considered a vigorous intensity activity during the time that one expends 8 METs during a vigorous ascent of the stair. Unfortunately the results of the 1996 USDHHS survey indicated that only 25% of adults engaged in these recommended levels and 29% reported no regular recreational physical activity at all. The incorporation of single sessions of 30 minutes of planned recreation activity each day is a dramatic behavioral change for most Americans that require an investment in time (activity time and travel time) and cost (fees and equipment). The focus on single 30 minutes sessions of planned recreation activity exercise may be a barrier for many sedentary adults to initiating lifestyle changes such as active living that can benefit their overall health. There is evidence that people can achieve the same 30 minutes per day health benefit from the accumulation of short durations of moderate intensity activity, (Pate, Pratt et al. 1995; Jakicic, Wing et al., 1995) which suggests that closer attention should also be placed on opportunities for physical activities that can be generated from the activities of daily life that people engage in their workplaces, homes and public-oriented buildings.

The difficulty or indifference of working adults to engage in voluntary recreational exercise provides the motivation to consider how the design of office workplaces may increase opportunities for physical activity during regular workplace situations. Of the opportunities for the promotion of physical activity related to the everyday life activities within buildings, increasing the likelihood of workers taking the stairs instead of mechanical conveying alternatives stands out in its potential as an accessible means of health promotion even though the time spent traveling on stairs is relatively short.

There is scientific evidence that links physical activity from stair use with health benefits. The Harvard Alumni Health study of more than 11,000 men found that those who climbed at least 20 floors per week had approximately a 20 percent lower risk of stroke and of death from all causes (Lee & Paffenbarger, 1998). Indeed, several studies have found that increased stair use can have a positive impact on health (Tavani, 1999; Wannamethee & Shaper, 1999) and everyday stair use can improve the health for sedentary individuals (Boreham, Wallace et al., 1998; Boreham, Wallace et al., 2000). The ability to climb stairs is recognized in many medical studies as a indicator of health (Freedman & Martin, 1998; Ferrucci, 2000; Gregg, Beckles et al., 2000).

Stair use can provide a particularly cost-effective opportunity for moderate intensity physical activity. Every multistory building contains stairs, and people can use stairs without special equipment, changing clothes or membership fees. While the typical duration of any specific event of stair use is unlikely to singularly fulfill the Surgeon General's recommended 30 minutes of moderate intensity activity, stair climbing provides an opportunity for moderate exercise when combined with walking for purposeful travel or recreation that is lost when alternative mechanized devices such as elevators and escalators are used. Stair use, whether incorporated into walking trips within a building to achieve a ten minute or more burst of moderate activity or done to climb a single flight of stair can build strength, increase endurance, burn calories, prevents muscle mass loss due to aging (Health Canada, 2003) and contribute to changes in attitudes and behaviors towards physical activity.

The potential health benefits of any physical activity must also be compared to the associated risk of injury that is always possible when engaging in physical activity. Statistics indicate that falls on stairways are the second largest cause of accidental death (6,200) after automobile accidents (45,000) in the United States (Templer, 1992b). However 80% of all stair falls occur in the home and 75% of all deaths resulting from stair falls are individuals past the common working age limit of 65 years. The risk of injury from stair falls can be lessened by addressing the environmental and host-related causes. Environmental causes are attributed to the safe design and maintenance of stairways such that they are appropriate for their use, population and environment. Host–related causes are attributed to the stair user's physical and cognitive limitations due to the effects such as aging, medical conditions, medication and their behaviour while using the stair. Most office workplaces provide the organizational structure to manage these risk factors by controlling the standards of design and maintenance of their environments. In addition, host-related causes are lessened by policies that generally limit the age and establish standards of decorum within the workplace such as limiting employment to those under the age of 65, restricting reckless behaviours and addressing those with health issues with the mandated provision of elevators.

It is the basis of this study that, when the inherent risks of stair use are controlled, stair use may provide for a cost effective and accessible means of increasing physical activity and resulting health benefit to the millions of North American adults who work in office workplace buildings. It may be possible to promote the health benefits of moderate intensity physical activity in office workers through the design of buildings that facilitate stair use.

1.3 Building Regulations and Stairs

North American building regulations have designated stairs as an important component of vertical circulation for emergency exiting from buildings. Building codes utilize multiple strategies to minimize the impact of fire within building including the classifying of buildings by risk to occupants and type of use; control the spread of fire within buildings and from one building to another; the provisions of safe paths of egress including corridors; stairs and ramps, in emergency situations; and the distributions of exits throughout the building prescribed distances of travel. Building codes establish minimum standards for the number and width of stairs relative to occupancy, the size of treads, risers, landings and handrails; the construction of the stairwell enclosure to prevent the spread of fire and smoke while exiting, and distribution of stairs to provide paths for egress throughout the building.

This has resulted in the creation of a specific stair typology, the fire exit stair. Fire exit stairs, due to their focus on the means for safe emergency exiting, are generally segregated from adjacent building spaces, have minimal interior finishes and are located to ensure distribution related to each other. Building codes place do not dictate the actual location of stairs or that stairs be built to encourage awareness of their location through daily use. The only requirement addressing user awareness of stairs within a building is the provision of illuminated exit signage. The most common type of stair provided for general travel in buildings is often open and articulated stairs located within the lobby or atriums of buildings. Building codes also place limits on the number and the location of open stairs, sometime limiting their location relative to the closest building exit and other parts of the building to conform to maximum allowable travel distances.

Building code requirements for stairs are generally prescriptive, providing the specific dimensions, formulas or coefficients to calculate the sizes and distances mandated rather than allowing architectural designers to utilize alternative approaches to achieve safe exiting strategies. Architects receive limited information on how the prescriptive requirements have bee developed and thus lack knowledge and experience for developing alternative performance-related strategies for accommodating both the provision of emergency exiting and the promotion of stair use within a building.

1.4 Economic Aspects of Stair Design

Architectural design involves accommodating the wide range of personal, operational, climatic, regulatory, budgetary requests, needs and limitations of the building program resulting in the prioritizing the design of key expenditures in the building that either generate revenue or add value to the project; traditionally stairs are considered not to do either. However, elevators have been considered an asset to operations of building users, providing to the effortless and timely movement of people through the building. Today almost all multi-story buildings require an elevator to comply with barrier-free access requirements. However the provision of more than one elevator in buildings of 3 to 4 stories may be an expensive luxury. Based on its initial cost, the cost of providing a second hydraulic elevator is approximately $38,000[1] per floor. By comparison the cost of a most stairs that provide ancillary service to the same floor levels range from approximately $15,000 per floor for an enclosed fire stair with minimal finishes to $20,000 per floor for an enclosed stair use with upgrades floor, wall, and ceiling finishes compatible to public corridor finishes. Unfortunately most enclosed stairs are rarely used or considered as a cost effective alternative to elevator use, even through they must be provided by building code regulations. In some buildings, elaborately articulated stair are provided in lobby areas for use as alternative means than the elevator for the travel of one story up or down. The cost of a articulated lobby stair is approximately $65,000 making one an expensive item in comparison to the elevator. According to a leading commercial real estate broker[2], neither the provision an open stair connecting upper floors or the provision of additional elevator will result in additional rent revenue in most buildings. However there are certain tenants

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[1] This information is provided by Steven Clifford of Pelican Woodcliff Inc, Cost Consultants. Values represent costs current in December 2005.

[2] This information is based on a conversation with by Peter Mason of Cushman Lepage Commercial Realty, November 15, 2005.

such a government, personal service businesses and institutional tenants which may be attracted to ground floor and second floor spaces that are connected by a staircase which allow customers to avoid crowded elevators. This leads to some common assumptions within the development industry that stairs are not an asset for the operation and marketing of a building; stairs do not add value to the building; and the cost of stairs to accommodate certain tenants are expensive and do not generate revenue.

Economic assumptions within the building and real estate industry that stair use is limited to the provision of expensively appointed stairs might be providing a barrier to the provision of workplaces that encourage stair use. Although there may be argument that health benefit and savings in the construction costs of additional elevators could be realized by diverting vertical travel to stairs that are provided as a mandatory requirement for exiting, there is little evidence-based guidance to architects to better utilize these stairs in order to attract use.

An emerging interest in the well-being of workers, the cost to businesses from the effects of chronic illness and the cost of health insurance are contributing to the creation of healthier workplaces. Several corporate and government office workplaces such the Sprint Headquarters in Kansas City and the Caltrans Headquarters in Los Angeles have targeted stair use as an effective means of increasing the general fitness of their employees. These facilities have experimented and invested in innovative building designs that challenge traditional assumptions about the form and availability of stairs and elevators. While an economic analysis of stairs is not in the scope of this study, the identification of the features of stair in their buildings associated with stair use will provide a means of evaluating the validity of past assumptions and innovative approaches.

1.5 Potential of Stair and Building Design to Facilitate Stair Use

The foundation of this dissertation is vested in the notion that architects respond to both the needs and behavioral practices of their clients in the creation of buildings and once constructed the environment holds these behavioral patterns within the operations of these buildings, often making change difficult. A healthier workplace can be achieved by infusing the behavioral principles and attitudes that facilitate workplace physical activity through the use of stairs into the physical organization and attributes of office buildings.

This study focuses on one aspect of everyday physical activity: stair use. It does not deal with health benefit that may be derived from stair use. Rather, this study investigates environmental attributes that may encourage stair use in buildings. At the moment there is a substantial inventory of existing workplace buildings that have instilled elevator use as a primary means of vertical movement through the building. Previously cited studies suggest that interventions of motivational signage may result in moderate increases in stair use but do not substantially change the built-in reliance of mechanical options over stairs. This study provides a foundation for the development of key measures and strategies for the design of buildings that promote stair use as a fundamental feature of their architectural design.

1.6 Chapter Summaries

This manuscript presents a dissertation study focusing on the relationship between features of the physical environment and stair use within a series of analyses organized within the following chapters:

- Chapter 2 reviews the available literature in order to provide a means for approaching how stair and building design may influence stair use by proposing a framework for the identification and assessment of physical environmental factors and features that may influence stair use.
- Chapter 3 articulates the main questions of this study, the significance of this study and outlines the research design.
- Chapter 4 examines the utility of the theoretical framework proposed in Chapter 2 through an empirical study of the reasons for choice of route for both single level and multi-level travel within two buildings
- Chapter 5 articulates and operationalizes the constructs of the five themes of stair use (appeal, comfort, convenience, legibility and safety) and the methods and instruments used for data collection.
- Chapter 6 includes three statistical analyses of the data. First is an examination of the variance that exists within the identified physical environmental variables within the data set. The second inquiry uses a bivariate regression analysis to identify the key variables related to stair use within a sample of ten academic workplace buildings. The third inquiry uses multivariate regression to identify the set of key variables that explains stair use in this data set.

- Chapter 7 examines stair use and the key spatial variables identified in Chapter 6 through a graphical analysis of the ten buildings and provide a discussion of the spatial logic of stair use and two basic strategies for high stair use in buildings.
- Chapter 8 summarizes the key findings of the study and outlines the limitations of this study and future directions for research.

CHAPTER TWO:
RESEARCH DESIGN

2.1 Research Objective

The objective of this research study is to identify the physical environmental features of stairs and building designs associated with voluntary stair use in workplace buildings. Although previous stair use research has mainly focused on the immediate stair environment, this study will provide a foundation for research examining stair use at the greater building scale. This study will focus on stair use in academic buildings of 3 or 4 stories and use of a number of different research methodologies in order to identify, measure and discuss the possible role of specific physical environmental features of buildings that are associated with stair use. In addition, this study aims at identifying features and strategies of building design that encourage high overall stair use in workplace buildings.

2.2 Research Questions

The main question that arises from the objective is:

> What physical environmental feature(s) of stairs and buildings are associated with voluntary use of a stair within public academic workplace buildings of 3 or 4 stories?

The study draws on the limited scope of previous research on stair use. While previous research has utilized intervention studies to examine the role of specific physical interventions such as motivational signage or upgrading of interior finishes, this study will expand the inventory of physical environmental variables within the context of both the stair and the greater building environment in which it is situated for a specific population and organizational domain. This study will:

- Develop a theoretical and methodological framework for exploring the physical environmental variables which influence voluntary stair use;
- Develop tools and measures of stair use and the physical environmental variables of stairs and their buildings using methods and approaches from environmental psychology, spatial morphology and architectural design analysis;
- Conduct empirical studies of stair use within a set of buildings-in-use to examine, measure and visualize the impact of features of the physical environmental stairs and buildings on stair use;
- Discuss how the findings of this study may be incorporated into strategies for architectural design and regulations and the possible direction of further research on the topic.

To address these research questions and objectives, this study has utilized a multiple stage research program to examine the following research questions:

1) What does the knowledge and methods are available from previous research on stairs, health promotion, environmental cognition and architectural design offer towards the development of a conceptual framework for identifying and assessing the physical environmental features that may influence voluntary stair use?

2) How do building users understand their reasons for choosing to use stairs within the context of purposeful travel through a building? How does this conceptual framework enlighten us about the relative influence of features of the physical environment on stair use in an academic building setting?

3) What tools and measures can be developed to operationalize the broader thematic concepts identified in the thematic framework (Convenience, Legibility, Appeal, Comfort and Safety) for stair use within academic workplace buildings?

4) What variability is present within the identified operationalized variables of the thematic framework in a sample of 10 academic workplace buildings-in-use?

5) What relationship is present between the operationalized variables of the thematic framework and stair use within the sample of 10 academic workplace buildings-in-use examined in this study? This stage test the following hypotheses developed within the scope of this study:

- Stair use is influenced by the relative location and accessibility of stairs within buildings that operationalize the **Convenience** of stairs for purposeful multi-level travel.
- Stair use is influenced by the relative visibility, imageability or intelligibility of stairs within buildings that operationalize the **Legibility** of stairs for purposeful multi-level travel

- Stair use is influenced by the relative appeal of a stair as a form, or the setting in which a stair is located within buildings that operationalize the **Appeal** of stairs for purposeful multi-level travel
- Stair use is influenced by features of the stair environment, which are compatible with the gait, exertion, or operational situation of the user that operationalize the **Comfort** within the stair environment.
- Stair use is influenced by features of the stair environment, which support and prevent injury or apprehension during use, that operationalize the **Safety** of stairs.

6) What are the key variables associated with stair use in sample of 10 academic workplace buildings-in-use?

7) What might the graphical analysis of the key indicators identified through statistical analysis, reveal about stair use patterns and the layout of the 10 academic workplace buildings?

8) What strategies for the design of building that encourage high overall stair are can be extracted from the study of the 10 academic buildings?

2.3 Research Methods

To address the sequential structure of the research questions, this study employs a multi-stage approach in developing answers to the main research question. This following section outlines the 5 phases of the study, which are discussed in greater detail in the subsequent chapters.

Phase 1, which is presented in Chapter 3 employs a review of the available literature to establish a thematic framework for the identification and assessment of the physical environmental features that may influence voluntary stair use in public workplace buildings. The framework is developed from published studies and text from the various disciplines and fields of study including:

Architectural Design, History and Theory

Environmental Cognition & Behaviour

Building Codes & Regulations

Stair Safety

Public Health and Health Promotion

Phase 2 examines the thematic framework by asking building users within two buildings in a self-report survey to identify their reasons for route choice for both single floor and multiple floor travel. This study tests the structure of the thematic framework and examines the relative influence each theme may have on stair use within the buildings. This phase is discussed in Chapter 4.

Phase 3, which is presented in Chapter 5, outlines those variables that are the focus of this study by developing operational definitions, quantitative measures and/or graphic representations of the five thematic concepts and their constructs. Data on stair and elevator use and the identified variables is collected on 38 stairs and 12 elevators located within ten academic buildings for analysis in phases 4 and 5 of the study. Stair use (on the best-used flight) and elevator use is measured using active infrared monitors, for 8 hours for 5 consecutive days to determine that percentage of vertical travel attributed to each stair and elevator. The study uses various means and equipment including space syntax techniques to measure the 20 physical environmental variables identified for study

Phase 4 uses statistical analysis to examine the relationships between measurements of stair use and the 20 physical environmental variables identified in the previous chapter. Chapter 6 presents an analysis of the variance within the physical environmental variables within a sample of ten academic workplace buildings. The study uses the bivariate analysis to examine and test the research hypotheses related to stair use and the operationalized variables of convenience, legibility, appeal, comfort and safety. Multivariate regression analysis is used to identify a small number of key physical environmental indicators of stair use.

Phase 5, which is discussed in Chapter 7, presents a graphic analysis of the ten buildings to explore the key spatial variables that explain stair use. This phase utilizes the statistical findings developed in previous chapters to examine how the position of stairs relative to a small set of key physical environmental variables explains stair use patterns in the 10 buildings. This phase identifies strategies for the design of buildings that promote high levels of stair use.

2.4 Scope of Research

This research study examines stair use within public academic workplace buildings. Ten academic program buildings are selected for this study in order to provide a public workplace setting for study in which the use of stairs for vertical circulation is higher than expected in most public workplace buildings. High levels of vertical circulation are due to the requirements for movement to activity specific spaces (classrooms, labs, lecture auditoriums) within the daily common use of the buildings. All buildings selected for the study are 3 or 4 stories in height. This limits any singular incident of one-directional vertical travel to 3 stories (a study of stair use in a 4 story office building found that workers were willing to climb a maximum of 3.5 floors (Kerr & Eves, et al., 2001)).

The use of academic program buildings provides for a population sample of building and stair users, which is principally adults, between the ages of 18 to 65 years of age (although the majority will be under the age of 25 years), having employment or academic activities within the building on a regular weekly basis. Academic buildings provide for both organized and structured activities in the buildings such as classes and freely scheduled activities such as libraries and vending machines. This provides for a building population that makes many internal trips within the building each day rather than travel between the building entrance and only one specific destination within the building. The principal workplace activities in each building occur within the hours of 8:00 am to 6:00 pm.

The academic buildings in this study contain both only stair and elevator options for vertical movement. To increase the generalizability of the study to other workplace buildings and to address security concerns of the building management, the collection of stair and elevator user data for the study are restricted to 40 hours per building accumulated in 8 hour period on 5 consecutive work days between 8:00 am to 5:30 pm. Stair use data and variable measurements are also restricted to the period between the start of the third week and end of the last three weeks of an academic term and during weeks when no extraordinary activities such as open houses or receptions were to occur to maximize the observance of everyday patterns of vertical travel within the buildings.

2.5 Relevance of the Study

This study furthers our understanding of the role of the physical environment in predicting the voluntary use of stairs. Taking the stairs instead of mechanized alternatives can provide an accessible means of improving health. While several health promotion studies have identified means such as motivational signage, artwork, music and upgrading of interior finishes as means of increasing stair use, these interventions have generally produced only marginal increases in stair use and there is some evidence that their effect diminishes back towards baseline use over time. In most of these studies, interventions which introduced new environmental features into the immediate stair environments were use to attract people who would normally have used either a nearby elevator or escalator. While these studies provide an important foundation for the effects of environment on stair use, there is a need to identify the wider range environmental features that may influence stair use. To date there has not been a study that examines the possible correlation between stair use and a comprehensive range of physical environmental features of stairs and building layouts in public buildings within a multiple building sample.

In addition, understanding the determinants of stair use may assist in the design of intelligible, safer, cost-effective and healthier building environments. Stairs have the potential to play an important role in wayfinding within multistory buildings, especially low-rise buildings such as hospitals, convention facilities, airports, and schools. As multiple stairs are required in all buildings over one story, there may be a substantial savings in construction and operation cost by avoiding the provision of more than one elevator (one is required for barrier-free access regulations) by promoting stair use. In addition, promoting the use of stairs within buildings may also address some possible safety concerns associated with stairs including alleviating the isolation of the stair environment that may promote unsafe conditions that may result in physical and psychological harm due to neglect, incongruity or crime. Stairs are an important element in the emergency exiting strategy of building codes; elevators are generally neither safe as a means of building egress due to smoke movement nor accessible when required for firefighter’s use. However it is a reasonable assumption that it is safer to know where the stairs are located when needed for exiting in an emergency situation. If stair use breeds familiarity with its location and availability, promoting stair use in buildings enhances the exit strategies required by building regulations.   However the primary motivation of this study is based on promoting the design of healthier buildings that support healthy behaviours such as physical activity especially within workplace buildings.

The results of this study can provide evidence to address several issues related to the stairs and architectural design:

- The guidance in the development of evidence-based architectural design strategies supported by conceptual models, analytical tools and measurements for the development of buildings that promote stair use.
- Provide guidance in addressing both the promotion of stair use within the requirements of building codes that regulate the placement and size of stairs for exiting purposes
- Provide guidance in reconciling the promotion of stair use as a program objective in architectural design with the economic restrictions of a building budget

The results of this study can provide a means for balancing the potential health benefits available through the design of buildings environments that promote stair use with the regulatory and economic considerations of building design that have generally limited stair use in workplace buildings.

CHAPTER THREE:
A FRAMEWORK FOR THE IDENTIFICATION OF THE PHYSICAL ENVIRONMENTAL FEATURES THAT MAY PROMOTE VOLUNTARY STAIR USE IN PUBLIC WORKPLACE BUILDINGS

This chapter will examine the theoretical foundation and research approaches for the study into the relationship between physical environment and stair use based on a review of the available literature of three disciplines: health promotion, environmental cognition and architectural design. Health promotion research offers a number of research perspectives and approaches resulting from an increasing focus on the behavioral, educational and environmental factors related to physical activity. Research related to improving health through stair use has to this point in time however focused on interventions such as the types of motivational signage or environmental enhancement required within the local stair environment to increase stair use. The perspective that stair use is linked to travel throughout a buildings suggests that environmental cognition perspectives, principles and techniques can contribute to an understanding of how stair use is also related to the way people understand and move through buildings. Architectural literature provides additional insight into the way that formalistic and technical aspects of stair design may affect use. This chapter uses a review of the literature to develop a conceptual framework for identifying the physical environmental features that may influence people to voluntarily use stairs.

3.1 A Health Promotion Perspective

Development of health promotion theory, research and application is primarily based on three basic perspectives towards health promotion: behavioral change and lifestyle modification, environmental enhancement and restructuring and a social ecological approach (Stokols, 1992; Green, Richard et al. 1996). From both a research and application outlook, these alternative perspectives provide different foci and means for achieving positive health outcomes. The behavioral change and lifestyle modification approach which focuses on changing individual attitudes and beliefs to achieve health promotion has been utilized in previous stair use research by targeting change in people's attitudes about taking the stairs. Some research studies have used motivational signs which links stair use to attitudes about healthy lifestyle, personal health outcomes and familial responsibility to promote stair use (Blamey & Mutrie, 1995; Anderson, Franckowiak et al. 1998; Andersen, Franckowiak et al. 1999; Kerr, Eves et al. 2000; Coleman & Gonzalez, 2001; Kerr, Eves et al. 2001; Marshall, Bauman et al. 2002). The environmental enhancement and restructuring approach targets changes in the quality of social and physical environments which improve aspects such as hygiene, safety and satisfaction of an environment to support changes in personal and social healthy behaviors. This approach does not require changes in a person's existing attitudes and beliefs towards their health choices but makes environments more accommodating for the engagement of physical activity. This approach has also been used in some research studies aimed at promoting increased stair use through environmental enhancements that change the comfort and appeal of stairwells by adding art, music and improved interior finishes to an existing staircase (CDC, 2002; Kerr, Yore et al. 2004). Both approaches place primary emphasis for change in altering one domain within the complex and interdependent system that structures human activity. A social ecological perspective provides another approach to stair use research by addressing the complex factors that determine health outcomes by providing a structure to identify and examine the interdependence between the individual, social systems and the physical environment. This approach recognizes that a mixture of individual, social organizations and environment factors act to predispose, enable, reinforce or change individual or collective behaviors towards health and healthy lifestyles. The strong point of this perspective, when applied to research, is that it can utilize aspects of the other approaches but provides for a more comprehensive and perhaps realistic framework for assessing the attributes and factors of a human system. This allows for the recognition and achievement of the best fit of active interventions (educational, motivational and environmental interventions) and passive design (embodied in the personal, social and environmental features of a system and its components) for achieving positive health outcomes.

The resources available and ability to which change can be achieved in individuals, organizations or physical environments will affect the choice of health promotion approach. A combination of these approaches was used in a stairwell at the CDC office building in Atlanta (CDC, 2002; Kerr, Yore et al. 2004), where both motivational signage and environmental enhancement were made to an existing fire stairwell in order to increase stair use. While intervention studies can address possible causal relationships between the environment and stair use, one shortcoming of this method is that this approach has limited the scope of research into the determinants of stair use to those features that can be easily and economically changed within existing stairwell. This economy has resulted in the use of motivational signage and interior enhancements being quickly accepted and implemented by building managers interested in increasing stair use in existing buildings. The goal of designing buildings that promote high level of overall stair use may require a more social ecological approach.

3.2 A Social Ecological Approach

The social ecological approach offers some strength over the use of a single domain approaches in that it can integrate both the strategies of behavioral change and environmental enhancement perspectives. It also provides a framework for identifying and assessing the complex number of factors that may influence human activity. This approach is applicable to investigating both existing and new social and environmental settings. However, this complexity of influences also exposes its primary weakness in this approach; that it is difficult to identify and determine which of all the various factors that have potential influence within the domains and activities of a different human system have the greatest influence.

In practice one can build on the strength and manage the weakness of the social ecological approach by focusing on how influencing factors and environmental settings can be generalized within the personal, social and environmental factors across different settings such as office workplaces, educational facilities, or transportation facilities. Although the precaution here is that one size may not fit all, effective advancement in health benefit from stair use could be realized by identifying and targeting large sectors of the adult population where some generalization of the key environmental factors that influence physical activity and stair use may exist.

This study proposes a social ecological approach for voluntary stair use within public workplace buildings. Public workplaces offer great opportunity to encourage multi-level travel use by stairs for everyday travel. Census information (U.S. Census, 2000) indicates that almost 60 million Americans (representing 46% of the American working population) work in office and administrative support, professional, management, financial and related occupations which are generally located within office workplace environments. Federal and state government agencies alone account for over 3.6 million office workers (Zimring, Joseph et al. 2005).

A framework for assessing the physical environmental features of voluntary stair use will build on the previous research which utilized social ecological models, and research for physical activity and analysis of public buildings. This study will use the profile of possible personal and social factors, provided in Table 3.1, that has been previously identified within health promotion research as determinants of physical activity (Pate, Pratt et al. 1995; King 2001; Bauman, Sallis et al. 2002). While the personal and social organizational profile of determinants of stair use requires further research to refine its application for stair use, this was not the objective of the study. It however provides a basic outline of the types of factors, which might influence stair use within workplaces.

Table 3.1 Personal and Social Organizational Factors that affect Physical Activity

Personal Factors	Social Organization Factors
Personal Factors which have been identified as influencing participation in physical activity which may apply to voluntary use of stairs include the demographic, health variables, attitudes, beliefs, psycholgical or behavior attributes, beliefs and skills that may facilitate or impede efforts to participate in physical activity .	**Organizational Factors** include social and functional factors defined by the structure, culture and rules of the organization which reflect the opportunity for physical activity
Demographic and Biological Factors age gender education level genetic factors income/socioeconomic status injury history childlessness ethnicity	**Structural Factors** specialization of labor within organization separation of work groups within an organization **Functional Factors** job type tasks performed security provisions
Psychological, Cognitive and Emotional Factors enjoyment expectations and intention for exercise moods, perceived health or fitness level self-efficacy self-motivation	**Operational Factors** provision of communal services modes of communication utilized
Behavior Attributes and Skills past history being active dietary habits the process of behavior change **Social and Cultural Factors** physican influence support from friends, peers, spouse and family	**Organizational Attitudes & Policies** degree of socialability and interaction encouraged within the organization organizational policies towards the health of the building inhabitants

(Pate, Pratt et al. 1995; King 2001; Bauman, Sallis et al. 2002)

The focus of this chapter will be on establishing a framework for the identification of the physical environmental factors that may influence stair use in public workplaces. Physical environmental factors are defined as those aspects and attributes of the physical domain that may facilitate or impede efforts to participate in stair use. Our initial focus on physical enviromental features will be based on identifying the scope of environmental factors which may influence stair use or elevator use as a choice for vertical travel. While several environmental features which influence stair use such as motivational signage and the aesthetic quality of the stair environment have been identified in previously stair use research, (Blamey & Mutrie, 1995; Anderson, Franckowiak et al. 1998; Cheung and Lam

1998; Andersen, Franckowiak et al. 1999; Reisman and Gross 1999; Russell, Dzewaltowski et al. 1999; Kerr, Eves et al. 2000; Russell and Hutchinson 2000; Boutelle, R.Jeffery et al. 2001; Coleman & Gonzalez, 2001; Kerr, Eves et al. 2001; Kahn, Ramsey et al. 2002; Kerr, Yore et al. 2004), this study will examine research studies related to other modes of physical activity, specific aspects of stair and elevator design to identify the range of factors and their associated features that may influence voluntary stair use.

3.3 A Thematic Framework for Stair Use

Several health promotion studies have used social ecological models to examine the individual, social and/or physical environmental determinants of planned recreational activities such as walking and cycling (Giles-Corti, Donovan et al. 1996; Giles-Corti & Donovan 2002; Pikora, Giles-Corti et al. 2003)) The 2003 study by Terri Pikora, Billie Giles-Corti, Fiona Bull, Konrad Jamrozik, and Rob Donovan in particular provided a structural foundation from which the proposed framework of environmental factors for voluntary stair use was developed. This study structured the determinants of four types of walking and cycling activities (walking for recreation, walking for transport, cycling for recreation & cycling for transport) into four determinant themes (which they designated as Features) of the physical environment: functional, safety, aesthetic and destination. For each feature, the environmental elements that affect walking or cycling behavior were identified as items of the physical environment that influenced the physical activity. The relative importance of these features and items were then ranked for their relative importance using a Delphi study. This framework for the assessment of environmental features that promote walking and cycling, provided a structure that could be applied to identify and measure the relationship of the environmental features to many other types of physical activities.

While this model provides a useful structure for establishing an assessment framework for the determinants for two different physical activities (walking and cycling) for two different motivations (recreation and transport), application of the four identified themes (functional, safety, aesthetic and destination) are not necessarily transferable directly to all other types of physical activities, as in the case of voluntary stair use where the motivations and opportunities for physical activity differ.

Differences in motivation and opportunity can result in physical activities being classified in what will be defined as either recreational, instrumental or hybrid physical activities. Recreational physical activities such as walking and cycling for recreation are those activities where the purpose of the activity was for the participant to obtain a health benefit from purposeful exercise as one might receive if lifting weights in an exercise room. Voluntary stair use differs from the recreational physical activity that was the focus of the Pikora study (i.e.: walking and bicycling for recreation) in that voluntary stair use is generally not conducted as an isolated intentional exercise or recreational activity. While it may be true that athletes may utilize focused stair climbing in physical training programs, this is not an activity that we would commonly see in workplace and public building use. Voluntary stair use in an everyday sense is not an isolated or recreational exercise activity, but one most often predicated by other everyday activities such as walking through a building. This type of activity is defined as an instrumental physical activity, which is a physical activity that can produce health benefit as the byproduct of an activity in which exercise was not the purpose of the action such as walking and cycling for transport. Because the physical activity from walking and cycling was ancillary to the main objective of transport; the Pikora et al. study recognized that physical environmental factors related to purposeful travel including urban planning and transportation design influenced walking and cycling behaviors. In the case of voluntary stair use, using the stairs while walking from a personal workstation to a required meeting on another floor is an example of instrumental physical activity. As such, the proposed framework for voluntary stair use should also consider the influence of pedestrian movement and wayfinding within buildings on stair use. However, stair use may also be a result of Hybrid Physical Activity**,** which occurs when recreational physical activity may not have been the purpose for a primary activity but the individual makes an deliberate choice (which may be either preplanned or decided at a moment of opportunity) to take an option along a segment of the activity that provides for more physical activity than would occur if one chose to use a stair located adjacent of an escalator.

3.4 Environmental Cognition and Stair Use

The instrumental and hybrid nature of voluntary stair use results in both the consideration of the environmental themes which link stair use to the underlying activity of walking for purposeful travel through the building, and the nature and complexity of the decision-making processes that occur during wayfinding within a built environment. Environmental cognition studies suggest that people understand their environment and make decisions about movement based on three scales of understanding about their environment: local, relational and global (Zimring & Haq, 2003). This suggests that stair use should be examined in relation to multiple levels of spatial knowledge: at a local scale of the design and attributes of the stair, its enclosure and immediate adjacent surroundings; at a relational scale which reflects the spatial relationships between specific places or destinations within the building; and at a global scale which reflects how the stair is related to all other spaces within a building system.

It is likely that spatial scales influence stair use depending of whether stair use is an instrumental activity or a hybrid activity during purposeful travel. When people travel through a building is would be expected that they do so based on their larger understanding of the relational to global attributes of their route. However, in the situation where a person is presented with alternative options for travel, such as the elevator door opening just at the time one was about to take the stairs, the local to relationship attributes of a route may have greater importance in hybrid decision–making.

It is likely that the global, relational and local scales have different levels of importance in stair use dependent on the familiarity of building users with their environment. Buildings that generally attract one time users (visitors) may need to place greater emphasis on local and relational features of stairs and the building circulation corridors than buildings occupied by long term employees (occupants) who understand and travel through the building based on a relational and global understanding of building layout. This cognitive structure however is also complicated by the ways which people plan their trips or react along the journey in multi-story buildings. Individual trips may be dominated by the instrumental nature of walking and stair use for the efficient movement from one location to other. Building users may choose stair use as a hybrid activity by choosing paths that provides them with access to physical activity along the entire path. However in some incidences, when options such as adjacent stairs and elevators are presented to them along the path of travel, purposeful travel though the building may include both instrumental and hybrid activities.

3.5 The Identification of Possible Variables for Stair Use - A Review of the Literature

From a review of the available literature on physical activity, stair design, and environmental cognition, the possible physical environmental features which may influence voluntary stair use in public workplaces can be identified and categorized within 5 key themes: Convenience, Legibility, Appeal, Comfort and Safety. To introduce a fuller discussion of each feature it may be helpful to briefly define each theme at this time. Convenience is defined as the availibility, perceived ease of use, and expediancy provided by the use of the stair; Legibility is defined as the extent which the stair is discernible as an option for movement through the building; Appeal is defined as the presence environmental elements and features that affect the pleasurability and sensory appeal of stair use; Comfort is defined as the compatibility and usability of the stair in relation to physiological and psychological needs of the user; and Safety is defined as the perceived risk of injury or crime from within the stair environment. In the following sections, the possible environmental features of each theme will be identified from the literature in order to develop a proposed framework for the identification and assessment of environmental features that promote voluntary stair use. The social ecological model for voluntary stair use is presented in Figure 3.1 at the end of this chapter.

3.5.1 Convenience

Convenience refers to environmental features of stairs and mechanical alternatives (elevators, escalators), which directly address the instrumental nature of purposeful travel. In the case of purposeful travel, the choice of stair or elevator use is largely dependent on the features that support walking behaviors motivated by expediency, efficiency, exigency, and least exertion.

Several features that may facilitate the convenience of stairs are the number and availability of stairs and elevators, the proximity to building entrance and interior paths of travel, a stair's proximity to other spaces within the building, and the relative ease of accessibility are used to define the availability of stairs and elevators. While multi-story buildings are required by building regulations to have multiple staircases (BOCA, 1999), the number and location of staircases in a building may not correspond to the places where people most often walk and work. Building code requirements determine the number and location of stairs by occupancy loads and travel distances relative to size and shape of the building's interior and exterior configuration in order to provide a distribution of stairs for emergency exiting. The number (except for the provision of one ADA elevator) and location of elevators is not regulated in the same manner allowing architects to locate elevators in locations more convenient to the programmed activities in the buildings. The criteria for the provision of elevators during the design stage of a building is focused on issues of environmental availability through the number, size and speed of elevators relative to passenger demand, traffic control, and the relationship to building layout and circulation (Blanc 1996; Barney, 2002). This implies that stairs also need to address the features such as visual presence, travel time and metric length of routes, metric relationships between the programmed spaces and features of the building, proximity to predominate paths of travel or orientation nodes in the building that may influence stair use. This is further supported by research studies that have identified proximity to facilities for exercise and recreational activity (Blanc, 1996; Bauman, Smith et al. 1999) such as footpaths, and shops nearby (Blanc 1996; Corti, Donovan et al. 1996) and connectivity of neighborhood streets in promoting physical activity.

Convenience is also related to the way in which stairs and elevators are positioned within the arrangement of spaces that comprise the building as a system. This suggests that the features linked to the structure of movement within the building layout may play an important role in facilitating walking and stair use behavior within a building. Space Syntax methods and techniques provides a means for analyzing the behavioural characteristics of a spatial setting by measuring the relationship between human activity and the structure of inhabited space. Connectivity is a space syntax measure that quantifies the local relationship between each space and its immediate neighbor. Connectivity has been identified as a good indicator of movement between spaces especially when building users such as visitors rely on local and relational decisional-making in movement through the building. The spatial syntax measure of integration which measures the global characteristic of building of a spatial system has been identified as the best predictor of pedestrian movement in buildings gernally occupied by longterm occupants use (Zimring & Haq, 2003). A spatial analysis can reveal those paths of the building that are most related to the global structure of the building.

In both urban and building applications, the location of the most integrated paths in are a important predictor of the location of pedestrian movement (Hillier, Penn et al. 1993).

Stairs also need to address the environmental features that facilitate ease of accessibility and restrict expedient multi-level movement through the building. Many features of the buildings restrict the convenient movement of people including the presence of security provisions, temporary obstacle or poorly located permanent fixtures, crowding and high traffic demand. A few features that can enhance the accessibility of stairs include labor saving devices such as automatic door openers and magnetic door hold-opens devices.

Stair use as a hybrid physical activity may be dependent on the physical relationship between alternative modes of vertical transport which when faced with a situational opportunity would make one more desirable than another at a local level of decision making. Situational opportunity may be affected by the physical proximity between alternative choices along a path of travel, a well as qualities or functions that would make one option of travel more expedient than another. For example, in the case of stair and elevator use, a longer wait than anticipated for the elevator will alter a previous expectation of the elevator as being a faster method of travel than the stair. Elevator design theory indicates that the speed of the elevator and cab capacity and operations reliability are the main features of elevators that make people use stairs located adjacent to elevators in public lobbies (Edgett, 1994). In a similar manner, motivational signage is a feature of convenience, addressing the situational opportunity to improve your health by taking the stairs rather than the elevator.

Stair research suggests that learned and natural travel behavior such as rules for travel also influence route choice (Templer, 1992b). It was observed that people generally the accepted custom of following the rules of the road by staying to the right (depending on country) when traveling up or down stairs. Breaches of this etiquette were observed to happen at landings on stairs divided by a central handrail where crossings would provide for a taking a shortcut along the trip. This evidence asserts that people develop, in the absence of other information or instruction, behavioral tendencies such traveling on the right or traveling in the most angularly direct route to their destination (Dalton, 2001). This suggests that configurative features such as relative angular position of stairs and elevators in relation to paths of travel may impact on use patterns.

Thus features that address the convenience of stairs within a building layout include:

- Physical accessibility
- Connectivity of stairs/elevator with destinations or paths within building
- Relative position and angular orientation of stair/elevator to paths of travel
- Motivational signage
- Relative difference in distance of travel between stair & elevator
- Location of stair relative to most integrated paths of travel
- Connnectivity and integration values of stairs
- Elevator speed & capacity, operational reliability

3.5.2 Legibility

In this section, legibility is defined by the the discernability and intelligibility of environmental features used to make wayfinding choices throughout the buildings. Discerniblity relates to the way that people recognize presence and understand the purpose of stairs. Intelligibility addresses the way that the local attibutes of a stair are predicted by global characteristics of its spatial organization.

Visiblity and imageability play an inportant in environmental congnition and wayfinding. People exposed to a new environment recognize and make mental representations (cognitive maps) of local features and characteristics in order to understand their immediate environment; learning next to understand the relationship between features, nodes and landmarks, before developing a global understanding of the entire topological system of the building (Peponis, Zimring et al. 1990; Hillier, Penn et al. 1993; Dalton, 2001). While most people understand that multi-story buildings contain multiple stairs, visual recognition of the stair environment may be an important environmental feature for voluntary stair use. A stair that is not visible may receive little use. This cognitive mapping also involves the comparision and assessment of the new environment relative to cognitive models of similar environments developed from previous experience(s), cultural norms and prototypical models of stairs and elevators design and placement within building layouts. People can identify and assess in what circumstances a stair is to be used by the imageability of its combined visual features. For example, due to the specialization of stair forms and constructions, there are often great variability in the physical characteristics of stairs. One generally understands that articulated staircases in building lobbies are intended for bidirectional transit while minimally finished enclosed stairs are intended primarily for emergency exiting.

Intelligiblity addresses the spatial charcteristics of the building as a network of connected spaces. Intelligibility based on the degree that that local spatial characteristics of a specific space are predicted by the global structure of movement through the building. A simple example of this may be to state that a stair located along a main corridor of the building will likely to be more intelligble and easier to discern on a spatial level than a stair located in the back corner of a complex labrinyth of office workstations.

Thus features that address the legibility of stairs within their environment may include:

- Stair imageability
- Visual accessiblity
- Identification signage
- Visibility of stair from path of travel
- Visibility of other spaces from stair/elevator
- Intelligibility/complexity of building circulation paths

3.5.3 Appeal

For the purposes of the proposed framework, the term Appeal will be used to describe the provision of architectural articulated elements which are provided for visual appeal. Although other sensory stimulus such as sound and smell could influence the appeal of an environment, the visual sense seems to dominate human assessment of physical environments. Visually, environments can contribute to positive or negative emotional responses through the provision and composition of visually representational and formal qualities and attributes that address order, complexity, continuity, novelty, memory, character, symbolism and sentiment. Most publications on stair design written for the architectural community objectify stairs as aesthetic elements, compositions or constructions (Spens, 1995; Slessor, 2000; Dalton, 2001; Jiricna, 2001). There is an emphasis in this literature on the design of grand/ceremonial staircases located in areas of the building visually accessible to the public such as lobbies or building exteriors. While these publications provide an interesting inventory of the range of stylistic and formal approaches to stair forms and construction, they do not further the evidence that visual appeal influences stair use.

Previous research supports the importance of visual appeal in the human interactions with the built environment. Several physical activity studies have identified the presence of physical features such as trees, gardens, parks, interesting sights and architecture as influencing walking and cycling behaviors (Pikora, Giles-Corti et al. 2003). This is further supported by evidence that visual interest such views to natural environments can positively affect emotional satisfaction and well-being (Ulrich, 1984; Pate, Pratt et al. 1995). In an intervention study, an increase in stair use was observed in an existing enclosed fire stairwell, which received an upgrade to its interior, finishes, introduction of artwork and music (Kerr, Yore et al. 2004). This suggests that the visual quality of the form and finishes of the overall environment in which a stair is located and the presence of features which provide visual interest from or within the stair environment such as art, displays or attractive or interesting views may influence the voluntary use of stairs.

Thus features that may influence stair use by the provision of visual and form stimulation may include:

- Quality of the architectural finishes in the stair/elevator environment
- Presence of visually pleasing features
- Architectural articulation of the stair/elevator
- Views of and from the stair/elevator
- Continuity between the aesthetic features of the stairs and adjacent environments

3.5.4 Comfort

One of the distinctive differences between the use of stairs and mechanical devices such as the elevator is the amount of physical exertion and coordination required by systems of the body. The health benefit derived from the use of stairs, which results from increases in the metabolism rate and use of the muscles and skeleton networks can also be considered a source of discomfort or undue effort. There are several features related to stair user comfort identified in the literature that appear to influence stair.

One important issue of stair comfort is the ratio between the height of the riser and the width of the tread (Maraj, 2003; Kerr, Yore et al. 2004). The level of comfort or discomfort a person experiences is directly influenced by the height and gait characteristics of the user. As humans are not physiological uniform, this causes a problem for the design of a stair's risers and tread dimension that could be comfortable for all (Livingston, 1991; Templer, 1992). There are a variety of design guidelines available to give designers guidance on the most comfortable range for the riser/tread ratios (Templer, 1992; Edgett, 1994; Ramsey, 1994; Blanc, 1996; MMAH, 1997; BOCA 1999) to provide for the majority of the population. It is not however possible to design stairs that suit the physical needs of all people especially the very tall or short and the balance/mobility challenged. This literature also identifies that provision of intermediate landings to reduce the length of stair flight between stories may provide areas of momentary rest to stair users.

Features related to stair construction may also influence comfort including the structural and operation stability of stair and/or elevator. Structural factors not related to safety including deflection movements during travel caused by the dynamic loading of stair users, rigidity of handrail supports, vibration or mechanical noise of elevator operation, or history of elevator operation disruptions may also impact on the perceived or real comfort of stair or elevator use.

Even amongst the physically able population, their comfort level with stair climbing may be compromised by the way people use stairs. Personal encumbrances such as carrying heavy or awkward objects or situational encumbrances such as crowding or the speed of others on the stair (Hall, 1966; Templer, 1992) may influence personal comfort levels for using the stair.

Voluntary stair use may also be influenced by environmental comfort within the stair or elevator. Environmental comfort variables that may influence voluntary stair use may include factors such as temperature, wind, precipitation, humidity, noise, and sun control.

Thus features that address the physiological and psychological compatibility of people using stairs or elevators include:

- Riser heights, tread depths and tread/riser ratios
- Number of steps between landings
- Stair width/occupant load
- Environmental conditions within the stair
- Stair/elevator vibration & operational stability
- History of elevator service disruption

3.5.5 Safety

Stair climbing as an activity exposes the participant to more inherent risks than using mechanical alternatives. Injuries and deaths due to falls (including stair falls) in the United States are only surpassed in frequency by motor vehicle accidents (Templar 1992). Those with decreased agility, mobility, stamina, balance and reaction time caused by physical and cognitive disabilities from disease, physical impairments, aging, and substance impairment or those carrying large or heavy objects have an increased risk of injury from stair use. The provision of mechanical options such as elevators and escalators are an important safety feature and a statutory requirement for barrier-free access in multi-story buildings. This discussion will focus on the perceived issues of safety for ambulatory and cognitively-able individuals. Cognitively-aware individuals adapt assessment strategies when they make choices between stairs and mechanical modes based on their health and physical capacities and the features of the environment that may predict their vulnerability to potential injury from falls, unwanted behaviors or crime within the stair.

A broad range of attributes within the stair and its environment that can contribute to stair injuries due to falls (Templer, 1992; Pauls, 1982). These include: dimensional inconsistency and sizing incompatible to human gait of stair components specifically the risers, treads, nosing, tread wash and handrails/guardrails; flight length; lack of maintenance; poor slip resistance of the stair tread; poor visibility within the environment particularly of the tread edge use patterns; and changes in the physical and visual complexity of the environment especially at the top and bottom three steps of the flight where people are adjusting to their actions on the stair. Templer (1992) further suggests that stair configuration and use patterns such as speed of travel and crowding affect safety on stairs. Individuals need to assess the appropriateness of a stair's form and conformity to expected use patterns in determining their own use and behavior on the stair. For example, people may be more cognitively aware and thus more careful when approaching and using helix stair than straight flight stairs. However, as individuals tend to conform to the travel on the right rule in North America, people traveling on helix, dogleg and scissor stairs that ascend counterclockwise may tend to violate this rule to take short-cuts that increase their risk of injury .

The perception that staircases are unsafe places where one will experience crime or isolation may also influence stair use. Enclosed and scarcely used stairs can offer limited natural surveillance within the environment which according to CPTED principles (Jeffery, 1971; Paffenbarger, Hyde et al. 1997) increase the potential of the stair environment being used for socially inappropriate or perhaps criminal activity. For the same reason, it may be difficult to attract assistance in the case of an accident or crime within a rarely used staircase. The attention required during the three top and bottom transition steps may limit the individual's awareness of the overall environment making them more vulnerable to unanticipated encounters at these locations. The configuration of the enclosed stair environment provides very limited visual range to assess the entire scope of the environment in which the user is traveling. Poor or uneven lighting, limited visual clues within the stair increase the possible or perceived dangers within the staircase. The limiting of access to the building from the staircase due to security concerns to address safety concerns affects the physical accessibility (convenience) of stairs.

The Hale and Glendon model for behavior in the face of danger emphasizes the importance of previous experience and visual clues within a risk assessment and reaction strategy (Hale & Glendon, 1987). The six part strategy if applied to stair and elevator use would suggest that individuals 1) Develop expectations about the stair or elevator and its environment; 2) Develop a perception of the situation through scans of the environment; 3) Detect information about the environment identifying hazards or obstacles; 4) Develop understanding of what has been perceived; 5) Select a route, action and behavior; 6) React to missteps, hazards or obstacles along the path. This suggests that people assess safety based on visual clues within the environment and past experiences. Visual clues evident prior to use of a stair or elevator like obstacles, lighting levels, visual clarity of tread edges, graffiti, speed of travel, assessment of the number and behavior of people on the stair/elevator are likely to factor into point of decision-making assessments. Attributes of the stair such as dimension consistency of the risers, effectiveness of handrail support, stair deflection and vibration, or elevator operations which must be experienced will likely have less influence on a building visitor than a long-term occupant.

Finally, safety features that address perceived danger of injury or crime within a stair or elevator include:

- Visibility of stair tread edge
- Slip resistance treads
- Uniformity of riser height
- Uniformity and intensity of lighting level
- Maintenance level: presence of obstacles, hazards & graffiti
- Surveillance into and out of stair/elevator
- Security provisions

3.6 A Model of Influences on Voluntary Stair Use

A framework for the identification and assessment of the physical environmental features that influence voluntary stair use is proposed in Figure 3.1. While the framework's structure recognizes the personal and social/organizational factors that influence stair use, this study focuses on exploring the relationship between the environmental factors and voluntary stair use. The framework arranges factors of the physical environment into five themes: Convenience, Legibility, Appeal, Comfort and Safety. Physical environmental features, identified in the litertature, are organized in relation to their probable influence at the three different spatial levels of decision-making for stair use during purposeful travel.

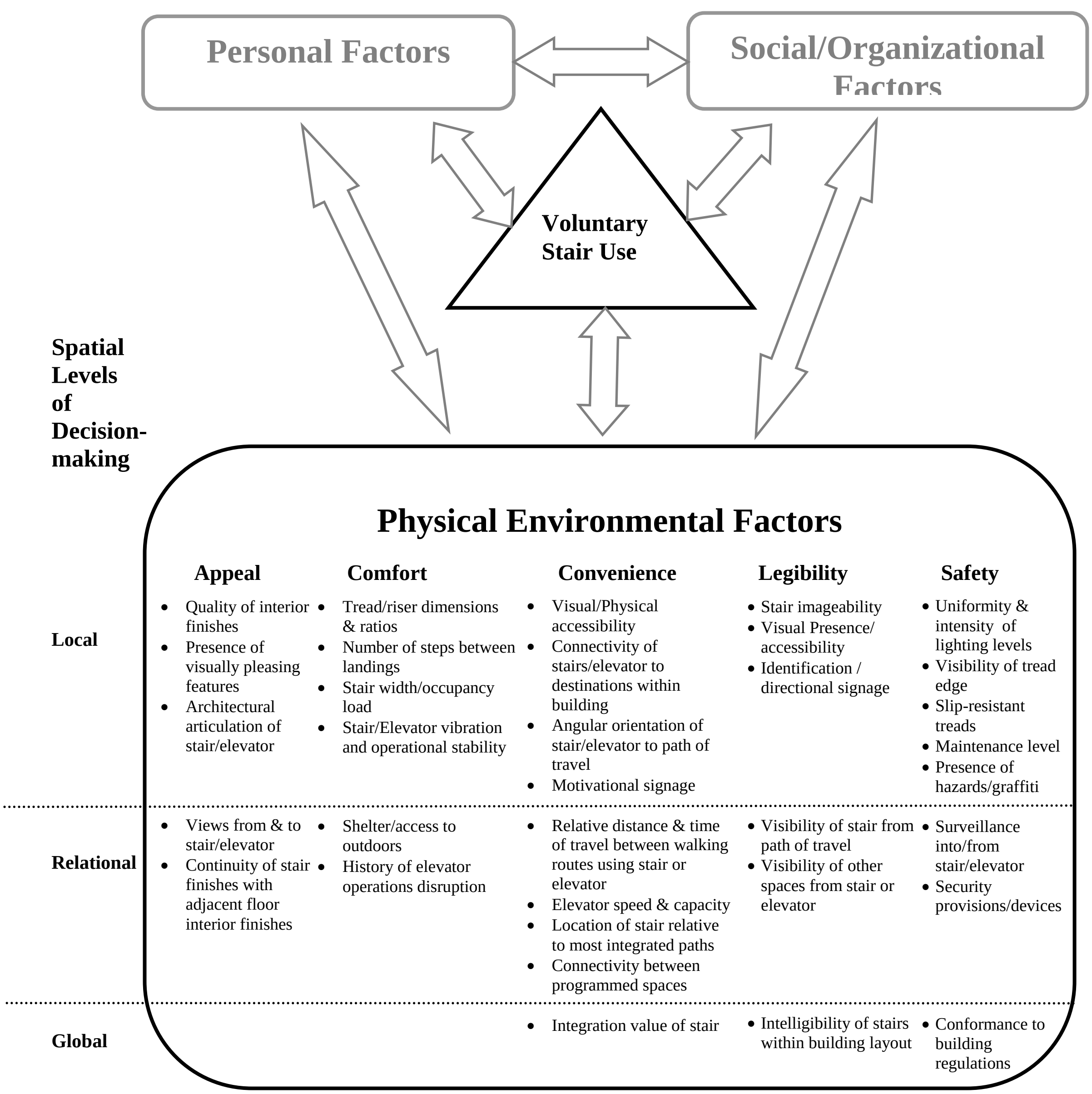


Figure 3.1 A Proposed Framework of the Physical Environmental Features that may Influence Voluntary Stair Use

CHAPTER FOUR:
A SURVEY OF REASONS FOR SAME LEVEL AND MULTI-LEVEL ROUTE CHOICE IN TWO BUILDNGS

This chapter evaluates the thematic-cognitive model for stair use presented in the previous chapter in relation to how people understand their reasons for choosing their paths of travel through a building. The objective of this chapter is to identify: 1) what features of the physical environment influence decision-making in multi-level travel; and 2) what is the relative influence of these factors and features of the physical environment on stair use. This chapter presents a study which surveyed occupants of academic buildings for their choice of routes for same level and multiple level travel through a building. This chapter is organized as follows:

4.1 Introduction

4.2 The Settings

4.3 Survey Design

4.4 Survey Results

4.5 Assessment of the Thematic Framework

4.6 Chapter Summary

4.1 Introduction

The framework proposed in Chapter 3 presents to some extent a cognitive perspective of stair use. The framework suggests that people may choose to use stairs based on: 1) their spatial understanding of the availability of options for vertical travel along the paths of their travel through a building; and 2) the way that they perceive that the physical environment of stairs accommodate their needs and expectations in regards to appeal, comfort, convenience, legibility and safety as they travel between floor levels.

This study will focus of a type of public workplaces where most work activities are sedentary and stair use is traditionally high: university academic buildings. University academic buildings provide a well-suited domain for this study. The populations of academic buildings generally share many personal factors such as age, health and fitness that would increase the likelihood of engaging in physical activities such as stair use. Similarly academic organizations are structured so that building users are required to travel to different places within the building to conduct generally sedentary activities such as listening to lectures, studying in libraries, or working in laboratory or studio spaces. As occupants of these buildings are required to move between places within academic buildings frequently and with some regularity, building users acquire a global understanding of the layout of the buildings various spaces.

In this study, a survey was used to investigate what features of the physical environment influenced the choice of routes of travel through two academic program buildings. Reasons for route choice for both same-level and multi-level travel involving stairs and/or elevators were collected and then analyzed in relation to the structure of the thematic-cognitive framework to determine the relative influence that the five factors and individual features may have on stair use. Reasons for same-level and multi-level travel were included in the survey, in order to compare differences in patterns of decision-making between these different types of travel. Including both same level and multi-level travel to addressed one specific concern with the use of a self-report survey. The concern was that a survey asking specifically about stair use may be subject to increased bias reporting due to the increase reporting in the media during 2003 on the dangers of sedentary lifestyles and the health benefits of physical activity. Many of these reports focused on the need to increase personal levels of physical activity and cited stair use in a positive manner over elevator use. There was a concern that survey participants may over-report or be biased in a survey focusing solely on stair use. To address this, the survey asked about only the last journey that participants made in a multi-story building. The survey participants would self-identify where they thought their last journey began and conclude at the location where they were asked to do the survey regardless of whether the survey participant changed levels, used the stair or the elevator.

4.2 The Settings

To optimize the available physical environmental conditions within the survey sample, the survey was conducted in two buildings which have similar ranges of population and organizational structure but different size and shape of building floor plans, and different distribution of stairs and elevators within the buildings. One of the principle features for the selection of these two buildings was the difference in the configuration of their building floor plan. One building had a small, compact floor configuration such that the horizontal distance of most travel along a floor level would be relatively similar in distance to the distance required for vertical travel by stair. The other building had a large, elongated floor configuration where the horizontal distance of overall travel along floor levels of most journeys would be relatively greater than the distance required for vertical travel. The elongated plan also provided more diversity in route choice and exposure to environmental features of the building than the compact plan.

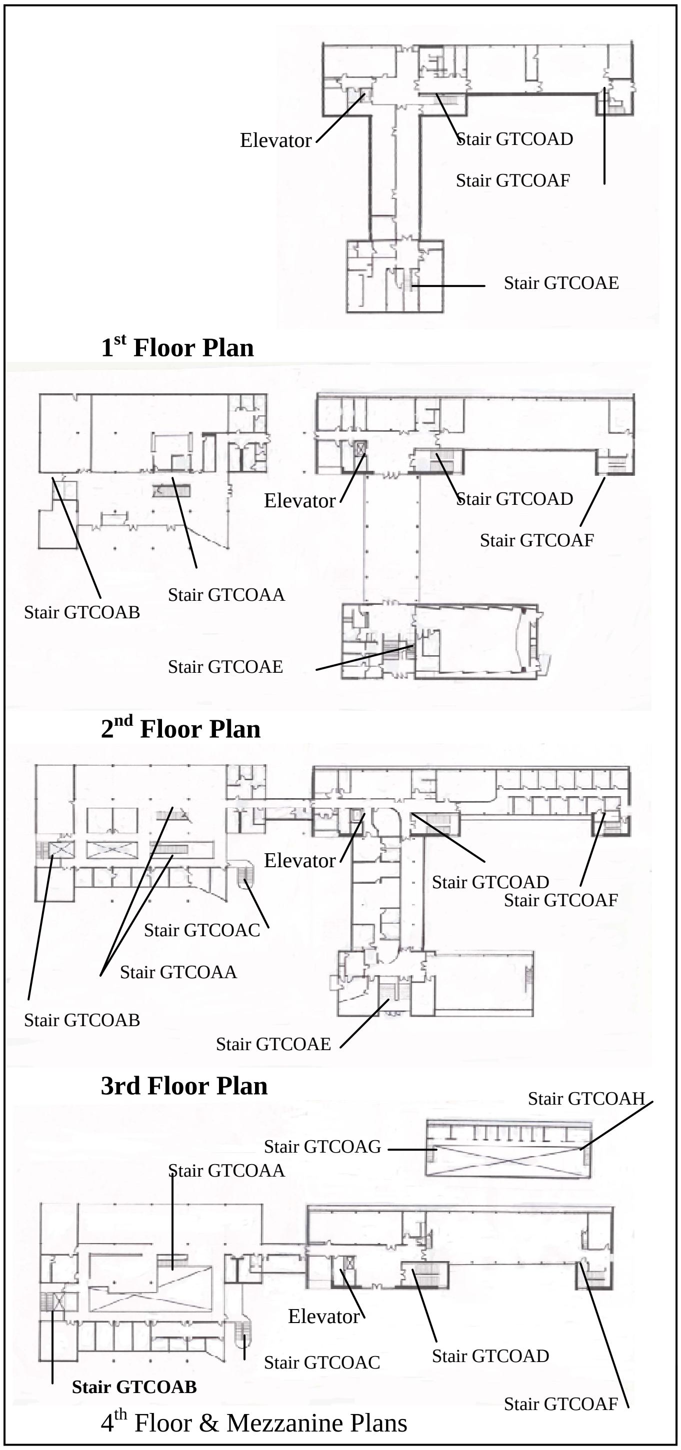
The two academic buildings selected for the study contained university architectural programs. The organizational system of both university programs were similar in that the spatial provisions for different modes of learning are provided by distinct and separate spaces within each building. These spaces include design studios, lecture auditoriums, classrooms, computer labs, offices, workshops and libraries. Students, faculty and staff are required to travel between some of these destinations several times a day. Both buildings provide similar range of ancillary facilities such as washrooms, lockers, coffee carts or vending machines, drinking fountains, areas where smoking is permitted outside the building, causal seating and display areas. It was observed in both buildings prior to their selection that there was a high degree of stair use amongst all user groups of both buildings.

Building GTCOA has an elongated floor plan (Figure 4.1). It is a large building comprised of 2 building components: an original structure and a later addition. The original structure is a 4 story building, which has its functional spaces arranged within long narrow wings which maximizes light and views from the studios and offices to outside courtyards and building exterior. In the 3 story addition, buildings spaces are arranged around the perimeter of a large interior atrium. This arrangement provides occupants with either exterior views from the functional spaces or views of the activities within the building's large interior atrium when walking along the circulation paths of this part of the building. The two buildings connect at the 2nd and 3rd floors only, resulting in travel through the exterior courtyards between the two buildings for some journeys at the ground level. There is a wide spatial distribution of the studio space, classrooms, library, auditorium, workshop and faculty offices throughout the complex. Differences in the grade elevations, the elongated plan and the provision of exterior staircases result in multiple points of entrance/exit to the building. The building has one passenger elevator and 8 staircases: including one grand staircase and two exterior fire exit stair and, five interior stairs. Stair use and elevator use was measured with active infrared monitoring equipment from 8:00 am to 5:00 pm during a 5 day work week period (the method is described in detail in Section 5.2). The data indicated that 94.4% of vertical travel was distributed throughout four of the eight stairs and the elevator. Stair and elevator use data is provided in Appendix A.

Building RYARSC (Figure 4.2) is a four-story building with a compact floor plan, which contains studio space and offices around the perimeter of an atrium space. The first level floor contains the major functional support spaces of the academic program including a large lecture hall, library, and workshop. Two of the three entrances to the building are at the first floor level. The main entrance to the building is located on the second level accessible by a large exterior staircase. The second level contains the main administrative offices, classrooms, presentation hall and studio space. Faculty offices are located on the south side of the atrium on the third floor. The remainder of the third and fourth floor contains studio space and support rooms. The building has one passenger elevator and three interior staircases: one central grand staircase located close to the elevator and two enclosed fire exit staircases. Measurements of stair and elevator use collected from 8:00 am to 5:00 pm during a 5 day work week period of the study indicated that 92.4% of vertical travel is conducted within the central grand staircase and the elevator both located in the building's central atrium space.

4.3 Survey Design

Building occupants were asked to participate in a survey designed to gather data on their reasons for their choice of route for the last journey they made through the building. An example of the survey for Building RYARSC is provided in Figure A.1 in Appendix A. Participants were asked to identify their starting point for their last journey and draw the route on floor plans provided on the survey and identify with an **X** any stops they made along the way. They were then asked for the journey that they had just illustrated, to identify the reasons for their choice of route from a list that was provided or write in additional reasons within a box below the list. Twenty-six reasons for route choice were developed from the literature review and pretest discussions with building occupants to identify a range of possible reasons for route choice. The list of reasons for route choice included reasons related to both personal factors and environmental factors for route choice but did not include reasons based on organizational features of settings that identify the purpose for the journey (e.g.: I had to attend class in the lecture hall). To force participants to focus on the decision-making process for their journey, participants were not given the option to check that the route was based on habitual patterns or to respond that they did not know within the list of identified reasons. These reasons could however be written in within box provided at the end of the list to included additional reasons that the survey participant wished to identify. During discussions and pretests of the survey, it was discovered that many building



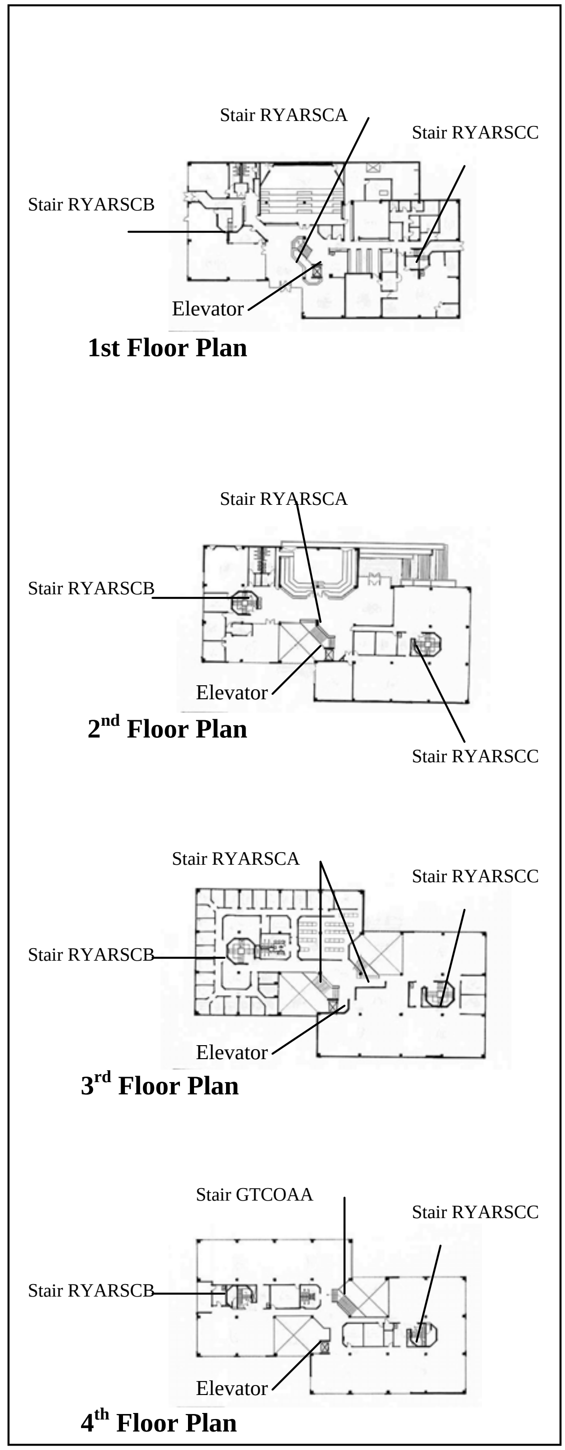


Figure 4.1 **Building GTCOA**
Elongated Floor Plan
Location of Stairs and Elevators

Figure 4.2 **Building RYARSC**
Compact Floor Plan:
Location of Stairs and Elevators

users left the building through the same doors from which they entered, often within close proximity to the stair used for travel. To explore whether there might be a the relationship between aspects of the exterior environment and stair use that are negotiated through the building's exterior doors, the survey asked which door the participant used for last entry and last exit.

One hundred surveys were conducted in Building GTCOA and one hundred and twenty surveys were conducted for the Building RYARSC during daytime hours while classes were in session from November 2003 through March 2004. Participants were selected so that the survey represented a distributed sample based on their location in the building so that all sections of the buildings were represented in the survey sample. The survey was designed to be completed within ten minutes including the introduction to the survey to maximize participant rates. Refusal rates were 2.9% for GTCOA and 0.8% for RYARSC.

Building occupants were selected and approached to ask to participate in the survey based on their location. An effort was made to distribute of survey throughout the building in order to optimize variation in route choices. The sample however included a high proportion of stair users during multi-level travel, but low proportion of elevator users. In the Elongated Plan, Building GTCOA, significantly more survey participants (77%) changed floor levels compared to traveling along the same floor level (23%). The percentage of survey participants who reported using the stair for multi-level travel was 93%, slightly more than the 87.1% measured using the active infrared monitoring equipment. In Building RYARSC, 55% of the survey participants reported using the stair compared to 85.2%

measured by the monitoring equipment. When early results of the surveys indicated an imbalance in stair users, twenty more participants were sampled in Building RYARSC resulting in a more even distribution between single level travelers (45%) and traveler that changed levels (55%) in the compact plan. Only 5 participants in each building (7% of the total sample) reported using the elevator.

4.4 Survey Results

Survey results indicated that people often cited multiple reasons for their choice of route for travel through the buildings. The data indicated that 99% of the participants identified more than one reason for route choice; the mean number of reasons provided per participant was 3.87. Survey participants provided four additional reasons for route choice to the list of provided in Figure A.1. Although few participates added additional reasons, the four additional reasons did identify specific environmental features of the route: *Closest to drop off from/to urban transportation, Least complex in terms of turns, and To avoid obstacles along the path*, and *Could travel outside for a portion of the route*. In addition, that their chosen route was their *Habitual route* was also added. Of the twenty-six reasons provided to the survey participants, only one reason *Stair/elevator/path too hot/cold* was not chosen.

The frequency of all reasons cited for route choices were arranged within a table (Table 4.1) within the thematic categories of the proposed framework that they addressed. The table organizes the results relation to the type of plan (elongated or compact) and if change of level occurred.

Table 4.1 Frequencies of Reasons Cited for Route Choice

		Travel along the same level				Travel across different levels			
		GTCOA Elongated Plan	%	RYARSC Compact Plan	%	GTCOA Elongated Plan	%	RYARSC Compact Plan	%
Physical Environmental Factors	Convenience	Fastest Route	65.2	Fastest Route	87.0	Fastest Route	66.2	Fastest Route	67.2
		Shortest Route	56.5	Shortest Route	85.2	Shortest Route	62.3	Shortest Route	56.7
		Most Connected to Other Stops	21.7	Most Connected to Other Stops	29.6	Most Connected to Other Stops	31.2	Most Connected to Other Stops	23.9
		Traveled the Most Well Used Path	8.7	Closest to Urban Transportation	13.0	Traveled the Most Well Used Path	11.7	Traveled the Most Well Used Path	25.4
		Habitual Route	4.3	Traveled the Most Well Used Path	11.1	Didn't want to wait for Elevator	6.5	Didn't want to wait for Elevator	19.4
		Most Convenient	4.3			Closest to Urban Transportation	2.6	Elevator was Unavailable	14.9
						Habitual Route	1.3	Habitual Route	4.5
						Elevator Cab was Available	1.3	Closest to Urban Transportation	3.0
						Most Convenient	1.3	Elevator Cab was Available	3.0
	Legibility	Most Visually Obvious Route	17.4	Most Visually Obvious Route	33.3	Most Visually Obvious Route	19.5	Most Visually Obvious Route	34.3
		Followed Most Visible Options along the Path	13.0	Followed Most Visible Options along the Path	27.8	Followed Most Visible Options along the Path	19.5	Likely to Meet Others	29.9
		Likely to Meet Others	8.7	Likely to Meet Others	7.4	Likely to Meet Others	9.1	Followed Most Visible Options along the Path	19.4
		Least Complex Route (turns/obstacles)	4.3	Unlikely to Meet Others	3.7	Unlikely to Meet Others	2.6	Unlikely to Meet Others	1.5
				Least Complex Route (turns/obstacles)	1.9	Least Complex Route (turns/obstacles)	1.3		
	Comfort			Stairs are Uncomfortable	9.3	Elevator Operations is Uncomfortable	3.9	Elevator Operations is Uncomfortable	7.5
				Sheltered from Climate	1.9	Sheltered from Climate	2.6	Stairs are Uncomfortable	4.5
						Could Travel Outside	2.6	Stair too Crowded	3.0
								Elevator too Crowded	1.5
	Appeal	Like View of Outside while Traveling	4.3	Most Visually Appealing Route	14.8	Most Visually Appealing Route	19.5	Most Visually Appealing Route	13.4
				Like View of Outside while Traveling	7.4	Like View of Outside while Traveling	13.0	Like View of Specific Interior Spaces	10.4
				Like View of Specific Interior Spaces	1.9	Like View of Specific Interior Spaces	5.2	Like View of Outside while Traveling	7.5
	Safety			Lighting Level	5.6	Lighting Level	3.0	Lighting Level	7.5
				Safest route	1.9	Safest route	3.0	Safest route	6.0
Personal Factors		Carrying Load	8.7	Fatigue Level	16.7	Prefer using Stairs	24.7	Prefer using Stair	26.9
		Fatigue Level	4.3	Carrying Load	14.8	Fatigue Level	7.8	Prefer using elevator	10.4
		Prefer using Elevator	4.3	Prefer using Elevator	7.4	Carrying Load	6.5	Fatigue Level	9.0
						Prefer using Elevator	5.2	Carrying Load	4.5
			n=23		n=54		n=77		n=66

Table 4.2 Frequency of Framework Factors Cited

Environmental Theme	Elongated Plan Building GTCOA			Compact Plan Building RYARSC			Both Schools	
	Stairs only	Single level only	All travel	Stairs only	Single level only	All travel	All travel	Stairs only
Convenience	92.7%	92.3%	92.0%	85.2%	99.3%	95.0%	91.4%	90.0%
Legibility	42.0%	69.2%	47.0%	52.4%	85.0%	70.8%	60.0%	47.7%
Appeal	21.7%	26.9%	22.0%	21.3%	18.5%	19.2%	20.5%	21.5%
Comfort	11.6%	0%	8%	11.5%	9.3%	10.0%	9.1%	11.5%
Safety	8.7%	0%	6.0%	11.5%	7.5%	9.2%	7.7%	8.5%
	n=69	n=26	n=100	n=61	n=54	n=120	n=220	130

The data indicates that most reported reasons for both same level and multi-level route choice were those that addressed issues of Convenience and Legibility of the path of travel. There was a large variance between the frequency in which of the most cited reasons for Convenience and Legibility compared to the most cited reasons for Aesthetics, Comfort and Safety. This difference is distinctive in that the most cited reasons for Convenience (*Fastest route (time); shortest route (distance); Most connected to other stops made; and Traveled the most well used path*), Legibility (*Most visually obvious route; and Followed the most visible options along the path*) and Appeal (*Most visually appealing route*) identify relational aspects of the path of travel while the remainder of reasons for choice of route identified specific local attributes of the route, stairs or elevator. There is a general consistency in the order of frequency and spatial structure of decision-making across the survey results for both buildings. This is further illustrated in Table 4.2 which presents a comparison of the overall frequency which environmental thematic factors were cited for both floor plan types; by stair use only, for single level travel; and for the combined survey sample. The five environmental themes rank consistently in ordinal importance for all types of travel and plan types.

Survey responses supported the fundamental assertion presented in Chapter 2 that stair use is linked with the primary activity of purposeful travel (tripmaking and wayfinding) through a building. Survey results suggest that the primary reasons for the choice of stairs or elevators within the two buildings were related to their relative position and visibility within the building layout. The survey did indicate that local attributes related to stairs were cited as reason for route choice among a small number of participants who used the stairs or elevators in the building. Such results are consistent with the expectation that a population group possessing a broad level of spatial knowledge about their building would rely on relational aspects of the environment over local aspects for trip decision-making. The following sections will examine the survey results in relation to the five thematic factors of the framework in greater detail.

4.4.1 Convenience

Four environmental factors related to the Convenience as an environmental factor were amongst the most cited in the survey: 1) *Fastest route (time); shortest route (distance);* 2) *Most connected to other stops made; and* 3) *Traveled the most-well used path*. These results illustrated in Table 4.1 suggest that convenience factors play the most important role in route choice regardless of level change or relationship of the proportion of vertical travel to the overall trip length of a purposeful journey. The survey results suggest that stair use is highly influenced by the distributional, relational and spatial aspects of a building's layout.

While no attempt was made to establish the time for individual journeys, the paths drawn by survey participants were analyzed in relative to the three other most frequently cited convenience reasons: 1) *shortest route (distance);* 2) *Most connected to other stops made; and* 3) *Traveled the most well used path*. Although users of the elongated plan (62.3%) and the compact plan (56.7%) identified that they took the short route (distance), measurements of actual journeys indicate that 28% (elongated plan) and 29% (compact plan) of stair users respectively did not take the shortest possible journey from their starting point to their destination. This percentage was also consistent with single level journeys in both buildings (26% and 29%). However, the survey participants who also cited the reason *Most connected to other stops made* did take the shortest route between the different stops. A review of the survey participants' route choices and plans of both buildings indicates several possible explanations for this discrepancy between reasons cited and actual behavior. Building GTCOA with its elongated plan provides for more choices of route for single and multi-level travel between some of the destinations. For example there are four different options available for travelers in the elongated plan for traveling to the same destination: different paths on different floor levels, different paths around the atrium, different paths within the interior of the building or through the exterior courtyard, and the option of stair or elevator use. Although the limited scale of the compact plan of Building RYARSC provided less options for routes than in Building GTCOA, survey participants also chose to bypass shorter journeys that utilized the elevator by staying on the paths of the atrium stairs or chose to walk a bit further to enter the classroom through the main doors within the atrium space even though the side doors provided a shorter journey.

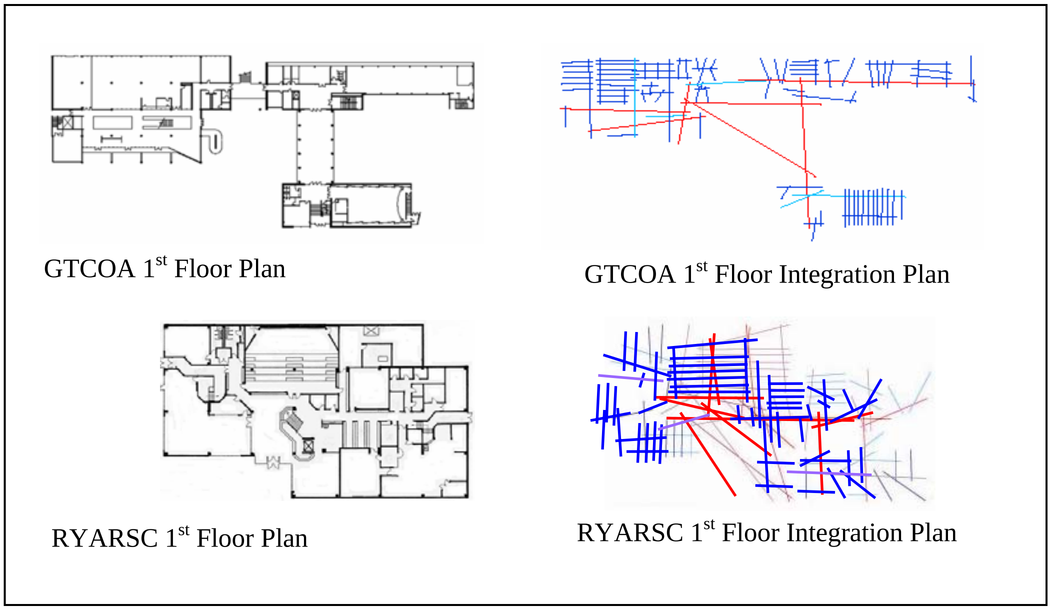


Figure 4.3 GTCOA and RYARSC Building and Integration Plans

The discrepancy between the participant's perception of shortest distance and their actual path of travel may indicate that convenience might not be measured purely by metric distance but might include other means of measuring the relationship between spaces within a building. For example, utilizing space syntax techniques, the building plans for both buildings could be reduced to an axial map indicating the relative values of integration between the longest paths which can connect the spaces within the building plan as illustrated in Figure 4.3. The technique which will be explained in the Chapter 5 provides a means for analyzing the spatial relationships of paths of travel in the context of an entire building layout. Briefly explained, the red lines of the integration plans (Figure 4.5) indicates the most integrated paths of movement with the buildings, paths where one might expect to find the most people traveling. In the case of the survey results, most of those who cited they took the shortest route (distance) but actually did not traveled along one of the most integrated paths indicated by the red lines in Figure 4.3. In the case of the students who walked past the side entrance to the classroom to use the main door adjacent the atrium, the main door was located adjacent to the convergence of the most integrated paths on the floor plan. They may have measured the convenience of their route with traveling along the most integrated paths instead or in combination to assessing metric distance.

Although building users who cited that they chose routes *most connected to stops they made* took the shortest route, most of the travel segments were relatively short, straight segments or with a high degree of visual connection between the stations of each travel segment. Most of these multi-level journeys were within the two buildings' atrium spaces which have the most connectivity to programmed spaces such as classrooms, computer labs, library, administration offices, coffee shop or vending machines. This suggests that the length of journey and the ability of the traveler to evaluate options for travel may include a variety of spatial attributes of a building's spatial organization including metric distance, , connectivity and integration of spaces within the building and extent of the visual field of travel.

4.4.2 Legibility

The two ***Legibility*** factors most cited: 1) *Most visually obvious route; and* 2) *Followed the most visible options along the path* demonstrates the two ways that people learn about their environment and use it to move through a building. Following the *most visually obvious route* suggests that travelers may address travel in buildings as movement through a series of domains which they can visually construct into a single path of travel between destinations. On the other hand, the reason, *Followed the most visible options along the path*, suggests that route choice may sometimes be considered as a series of individual path segments. Route choice is determined by the assessment of visual clues (local attributes) at the junctions of path segments.   Such visible clues are important to local to relational levels of decision-making. This suggests that stair use may be influenced by two aspects of legibility 1) the visibility of stairs as an option for travel along a path, and 2) the visual clues provided by a stair's imageability (Lynch, 1960), as to its availability and intended use as a path of multi-level travel.

The extent of visibility of and from the stair as well as visual connection between the floor levels and activities within the spaces it connects may influence stair use. Most survey participants that cited the reason *Likely to meet people* used the Stairs GTCOAA and RYARSCA located in the atriums of the buildings which have long visual vistas across the extent of their floor areas and the multiple levels of the atrium. These spaces provide both physical and visual connectivity to programmed spaces where people may gather or travel such as classrooms, library, administration offices, coffee shop or vending machines.

The relative visibility of vertical circulation options may also play an important role in route choice. In the compact plan, there is a distinct contrast between the visibility of the highly used central atrium stair and the other two stairs within the building. Atrium stair RYARSCA was used for 77.6% of all multilevel travel is highly visual and imageable as a means of vertical circulation within the building. The other two stairs, Stairs RYARSCB and RYARSCC, which collectively attract only 7.5% of the vertical travel of the building, are visually isolated, enclosed in fire-rated concrete walls with self-closing steel doors. This suggests that both quantifiable measures of visual exposure and qualitative assessments of stair imageability may be useful in explaining stair use.

4.4.3 Appeal

Three of the four travel/plan type categories in Table 4.1 identified three ***Appeal*** features: 1) *Most visually appealing route*, 2) *Views of specific interior space and* 3) *View of outside while traveling* as features of the physical environment that influenced route choice. Although appeal factors have been defined as the provision of architecturally articulated elements, environmental features or an effort at unique formal compositions, any which could provide visual appeal, the survey did not identify specific environmental features other than exterior or interior views as a reason for route choice. In both buildings, most survey participants that cited reasons of appeal for route choice used the visually complex space of the building's atrium which contained the grand stairs but also contained various displays, elements, activities, interior and exterior views or building corridors that offer a view of the exterior courtyards.

4.5.4 Comfort

A relatively low number of the survey sample cited ***Comfort*** factors (11.8%) such as *the stairs or elevator as uncomfortable* but without specificity. Only *crowdedness* (capacity) was identified as a specific feature of the stair or elevator environment. Shelter or access to the outdoor was specified by a few who utilized an exterior stair or utilized the longer path from starting point to destination through the interior corridor system in Building GTCOA instead of the shorter path through the exterior courtyard when it rained. A small number of participants did identify that *stairs are uncomfortable* or *elevators are uncomfortable* as a reason for route choice in multi level travel. However, 9.3% of survey participants in Building RYARSC also cited that *stairs are uncomfortable* as a reason for route choice for single level travel; perhaps choosing not to change levels because of uncomfortable stairs. In this survey the low priority of comfort in route choice can be explained by two factors: 1) academic buildings typically have high standards for their design and operations resulting in low occurrence of issues such as uncomfortable riser/tread ratios or structurally unstable stairs; 2) personal factors such as the youth and fitness level of the building population reduce the influence of issues of physical (dis)comfort.

4.4.5 Safety

Only two reasons related to ***Safety*** factors were available on the survey related to route choice: *Lighting Level* which is a local attribute of environments; and *Safest Route* a description that could include multiple aspects of the environment. A low number of people who cited safety as an issue of their choice of route (7.7%) although one visually evident specific feature of safety – low visibility due to light levels was identified. Graffiti and obstructions (furniture) were presence in only two of the buildings' stairs, both which have low usage: Stair GTCOAF (0.3 %) and Stair RYARSCC (2.5%) and although it has been previously mentioned as a possible feature that would influence stair use, it was not cited by any of the survey participants. It may be for further study whether graffiti and debris reduce the likelihood of stair use or are a product of low stair use. Overall however, organizational factors such as compliance with building codes, university operational, maintenance, and security policies also limit the likelihood of any of the stairs being below safety standards for the youthful population.

4.5 Assessment of the Framework

The survey study assessed the framework for one population and organization group (academic) only. The settings for the survey were chosen because they contained an active workforce with high levels of observed stair use and the organizational structure of the academic programs required frequent travel through the building thus providing a survey sample of building users with extensive knowledge of the building system. Based on the framework, it was expected that survey results would indicate an emphasis on the relational and global factors within the framework. While the results did fulfill that expectation, it was in the relative importance of the thematic factors that the survey provided the most profound insight. The data presented in Table 4.3 indicates the overwhelming importance (91.4% for all travel, 90% for travel with stair use) of Convenience factors in their reasons for route choice during purposeful travel. In addition, Legibility factors were cited by 47.7% of all travels using stairs during their journey. Interestingly, as the results indicate, fewer survey participants cited legibility factors for travel with stair use than for single story travel. In considering these results, it is noted that legibility was significantly less important in Building RYARSC where the difference in stair visibility amongst the three stairs is so great. It might be considered that RYARSC building users may not perceive the enclosed stairs as options for travel, making visibility not as important issue of conscious thought in that building (out of sight, out of mind).

The survey results in Tables 4.1 and 4.2 indicated that Appeal, Comfort and Safety factors also contributed to route choice in travel regardless of change of level throughout the building. Although the checklist format of the self-report survey method used provided mostly broad-based reasons for choice of travel routes, the result did identify that local features of stair travel such the presence of views, that the stair or elevator was uncomfortable to use, or lighting levels influenced their choice of route.

There are several key limitations to the survey phase of the study. One limitation of the study is its attempt to identify the features that influence stair use solely from the perspective of how people understand their own influences through their travel route through a building. The survey was not structured to ask participants to rank the relative influences of the reasons given. The survey indicates the frequency of reasons cited without identifying their relevance within individual route choices. This has limited the ability to understand whether relevance importance of each factor for different types of travel. For example, a building user may place some relevance on many reasons of convenience for their route choice although one reason such as the elevator was too crowded was the key determinant of the choice of route. In addition, the comparison between the reasons for route choice and actual travel routes indicated that behavior did not always relate to the reasons identified. People appeared to have a notion that the reasons for their route choice was that it was took the shortest distance from start to finish. However they failed to either identify or be aware of other aspects of their actual route such as identifying a journey through the interior corridors of the building as the shortest route (in metric distance) rather than the shorter path through a exterior courtyard. In this example, the traveler may either be poor judge of distance or cognitively does not equal travel within and outside the buildings equally. This illustrates some of the limitations of a cognitive approach in identifying the specific features that promote stair use in buildings. While the survey did provide great insight into the relative importance of the general thematic factors associated with stair use, the study not identify specific features that influence stair use in academic workplace buildings.

To optimize participation in the survey, the number and possible reasons for route choices were simplified to provide a wide range of likely reasons within the short time required to attract wide participation in the study. The survey pretests indicated that most building users were more likely to identify some reasons at a thematic level such as that the route was comfortable or safe rather than identify a specific physical features of the stair, path or building layout that made it uncomfortable or unsafe. This resulted in the mixture of thematic and feature-specific reasons for travel amongst the reasons for route choice included on the survey. Although this was useful in affirming the basic thematic-cognitive structure of the framework and the relative importance of the thematic factors that was cited by the survey participants, it did not provide an effective means for identifying and evaluating the influence of specific building features on stair use.

The survey sample was comprised of students, faculty and staff of two university buildings of contemporary North American building standards and is likely proportionately younger and more physically-able than the general population that would typically occupy public workplace buildings such as federal and state government office buildings. No one in the sample had visually identifiable cognitive or mobility disabilities or was accompanied by small children or the elderly. Both the demographics of the survey sample and the generally high standards of building operations and maintenance likely influenced the relatively low recognition of comfort and safety factors compare to what would be expected in a population that was better represented the age, state of physical ability and health of the general office workplace populations and more representative of the quality and range of public workplace facilities. The survey sample of the study is also relatively small (n=220) and while a decision was made to choose a setting with a high stair use (93%) in order to optimize the identification of the reasons that people chose to take stairs, the low number of elevator users (7%) limited the identification of environmental features that influence people not to take the stairs. While the two buildings were chosen to represent a large variance in stair features and building configuration, future empirical research must take into account the greater range and variety of stair and building designs within the public workplace sector.

Despite these limitations, the study supported the thematic and cognitive framework for the identification and assessment of physical environmental factors that may influence voluntary stair use within an academic setting and provided directions for subsequent phases of the research.

4.6 Chapter Summary

Chapters 3 and 4 have presented the preliminary stages of a multi-phase approach to examining the environmental features that influenced voluntary stair use in public workplace buildings. The framework' s structure recognizes that stair or elevator use is subject to the primary activity of purposeful travel and is also influenced by the depth of spatial knowledge that building users possess for use in multilevel wayfinding and situational opportunities.

According to the results of the study, the most reported reasons cited for both same-level and multi-level route choice can be categorized into the thematic factors of Convenience and Legibility. Most reasons defined within the framework for Convenience and Legibility are linked to the configurative aspects of the stairs and elevators within the building layout. Such configurative or spatial attributes are intrinsic to the design of the building as a system. Once established in the design and construction, these features and attributes have great and perhaps enduring influence on behavior within the building as they are structurally difficult or expensive to alter. The remaining themes of the framework Appeal, Comfort and Safety have an influence on local and relational decision-making during purposeful travel. This supports previous discussion stair use may be influenced by the local and relational properties of stairs and elevators, especially when these building components play a key role in route choice. One observation of the possible features of the thematic framework is that most features of stairs and building design that address the convenience and legibility support a single activity (purposeful travel) which practices change little over time. However, most of the features and attributes of appeal, comfort and safety also address a variety of activities or social, cultural and personal influences of the building's population. This suggests such factors are also influenced by the socio-cultural aspects of building program and population and may be more subject to change over time. Some features addressing appeal, comfort and safety such as lighting or visual appeal, may have less influence on stair use than spatial attributes of convenience and legibility but are the easiest and least expensive to alter during the life of the building.

The next stages of this study will assume another approach to identifying and measuring the relationship between stair use and the physical environmental features of stair and buildings. While this chapter focused on a cognitive approach that investigated how stair use is influenced by the way people think about their environment and make decisions about their paths of travel, the next three chapters will stair use in relation to the way people use their environment.

CHAPTER FIVE: MEASURES OF STAIR USE AND THE PHYSICAL ENVIRONMENT

In the previous chapters, a basic thematic framework (Convenience, Legibility, Appeal, Comfort and Safety) was developed to identify the possible physical environmental factors, which may influence an individual's choice to voluntarily use stairs. The next phase of this study will identify and examine specific features of stairs within buildings, which operationalize the five thematic variables of convenience, legibility, appeal, comfort and safety.

This chapter describes three areas of the subsequent study: 1) the dependent variable and the physical environmental variables that were included in the study and the reason for excluding certain variables; 2) the way the variables were measured; and 3) the data collection tools.

The chapter includes:

5.1 Introduction

The thematic framework developed in Chapter 3 identified five concepts that may influence the voluntary use of stairs: convenience, legibility, appeal, comfort and safety. These terms are actually very broad and multi-faceted in their meaning. The five themes require clearer definitions that provide constructs which can be operationalized into quantifiable environmental variables. The remaining chapters of this dissertation will use the following constructs and definitions of the five factors of the thematic framework to identify and assess the physical environmental features associated with stair use. The thematic concept of Convenience has been defined by the three concepts: Proximity, Distribution and Accessibility. The thematic concept of Legibility has been characterized by three concepts: Visibility, Imageability and Intelligibility. Appeal defined by two concepts: the appeal of the setting (Setting Appeal) and the appeal of the stair as an object (Stair Appeal). The thematic concept of Comfort addresses three concepts: the compatibility of stair design to the human body in motion (Gait Compatibility); and the physical capacity of the human body (Exertion Compatibility); and the compatibility to accommodate the movement of socially engaged groups during travel (Social Operational Compatibility). The thematic concept of Safety is also characterized by the two concepts of Natural Surveillance and Maintenance.

Figure 5.1 provides a graphic representation of the research hypothesis. This chapter introduces hypotheses that will examine what features of the physical environment are associated with values for stair use in a study of ten academic buildings. The focus of the remaining cross-sectional studies will be to identify the features of the built environment that are associated with stair use. The study will not address the issues of causality and the role of any of the variables as mediators or moderators in the process of voluntary stair use. This study aims at identifying features that may lead to this type of research.

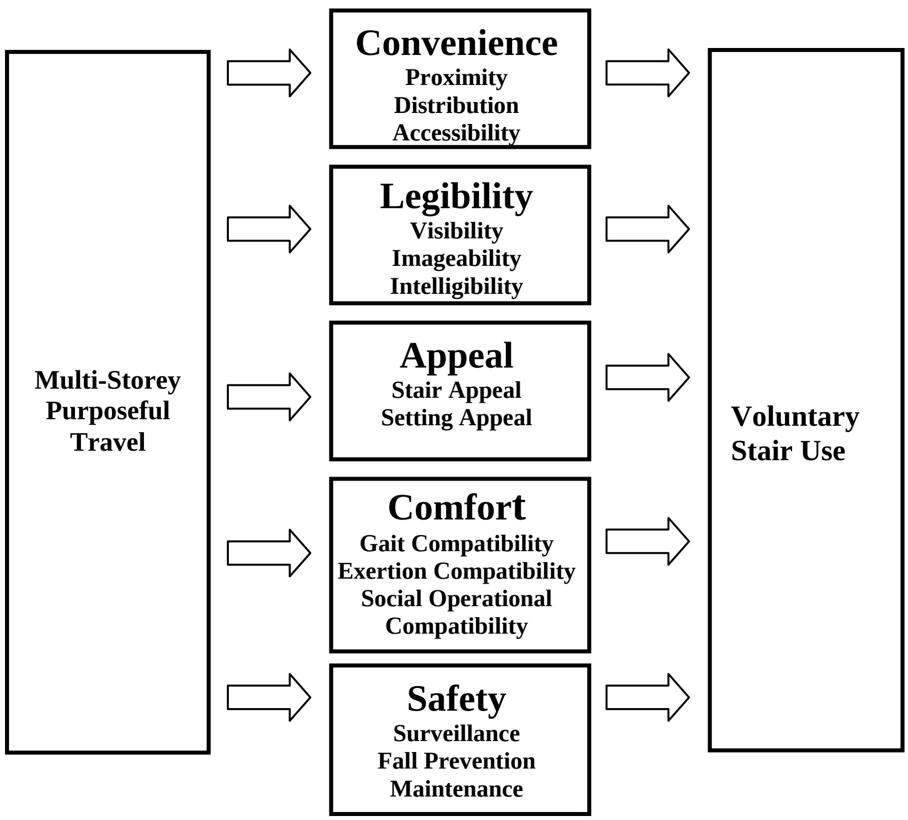


Figure 5.1 Conceptual Model of the Variables associated with Stair Use in Public Workplaces

The remaining phases of the study will utilize two different methodologies. Chapter 6 will use bivariate regression analysis to test several hypotheses that stair use is associated with features of the built environment that operationalize the five thematic factors of the framework. In addition, the study will use multivariate regression to identify a set of key variables of stair use. Chapter 7 will use a qualitative approach; using graphic plan representations to examine the how stair use is explain by the arrangement of key variables.

The remainder of the chapter describes the variables, which were included in the study and the method by which variables were measured and represented.

5.2 Dependent Variable – Stair Use

This study is interested in the relationship of physical properties of the stair and building environment and the amount a stair is used in relation to other choices, specifically the other stairs and elevator(s) within its building for vertical travel. Stair use is operationalized in this study as the percentage of total building vertical circulation attributed to each stair or passenger elevator within each building. The use of a percentage value for vertical circulation in each building neutralizes differences in the actual numeric values for vertical circulation due to different building areas and population sizes.

Vertical circulation within each building was measured using active infrared monitors. This study utilized the Model TM1550 active infrared monitor manufactured by Trailmaster Ltd. This device, which is primarily designed to monitor wildlife, was chosen due to is low cost, portability, accuracy, monitoring sensitivity and for the ease in which the data may be downloaded. In the case of stair use, the transmitter and receiver were placed in tamper-resistant wood equipment boxes, which were strapped securely underneath the handrail or guardrail of the most-used flight of the stair (based on pretest observations). The monitors were carefully aligned for accuracy and located past the third step down from the first landing. The equipment boxes were designed to not obstruct use of the handrails. Although the equipment boxes were painted a prime grey color to be as discrete as possible for a temporary installation, signage was required to be mounted near the equipment to ensure building users that the equipment installations were a sanctioned research project and that would not impose any potential danger to the stair or elevator user. In the case of the elevators, the transmitter and receivers were installed on wall rails located along the side of the interior of the elevator cab. The equipment boxes were installed as close to the doors of the elevator as possible. A sign were placed on the rear wall of the elevator cab at passengers' eye level to request elevator users to step past a line taped to the floor of the cab and to move to the back of the cab past the monitors to the back of the cab. The elevator data was divided by two to reflect the entrance and exit of passengers from the elevator. Use in elevators that did not have guardrails were counted visually by the investigator for a total 8 hours each in 30-minute sessions distributed throughout the day over a 2 month period in order to estimate elevator use for a 40-hour cycle.

Stair and elevator use was measured for consecutive 5 working days on each stair during weeks when no special events were scheduled in the building that may affect the typical everyday movement patterns through the building. The transmitters and receivers were placed in the equipment boxes each morning between 8:00 am to 9:00 am depending on the typical work schedule in the buildings and removed to download data and reset the receiver each afternoon eight hours later. Monitors were tested for accuracy each morning by the investigator who walking past the beam several times to check the operation of the equipment prior to resetting the monitors for the day's recording. The devices provide a record the time of each event which could be used to provide accumulative totals for stair or elevator use, the varying rate of stair use throughout the day and be monitored for evidence of tapering. In pretests, the equipment was tested for a range of possible methods of tapering. Pretest examined the potential for tapering that could be easily detected such as damage to the boxes or movement in the boxes position. The boxes were designed to minimize the opportunities to pry open the boxes or try to remove or move them from their position. The boxes were tightly strapped to the handrails with vinyl coated stainless steel strap clamps. The tighten mechanism was accessible only from within the lockable box. The pretests also investigated ways to identify and reduce other possibilities of tampering with the data collection. It was discovered that tampering could occur if someone moved past the beam several times in order to record phantom events of stair use. During the pretest period, the few observed attempts of tampering occurred on the first day of installation when a person waved their hand rapidly in front of the equipment box in an attempt to record multiple phantom events. It was determined that this type of tampering could be reduced substantially by adjusting the monitoring sensitivity of the equipment and by installing a small sign beside the devices that stated RESEARCH IN PROGRESS in bold letters with additional text describing that the study has been sanctioned by the university and their assistance in not touching or interfering with the equipment was requested. No other evidence of tampering with the equipment was observed during the pretests or the study.

The active infrared monitors used in this study emit infrared energy from the transmitter in short pulses less than a second apart, which is received by the receiver. The default frequency in these monitors is approximately 0.05 seconds. When the beam of energy is broken beyond the 0.05 seconds as is the case if a person passes through the beam while ascending or descending the stair or entering or leaving the elevator, the receiver will record this break as an event.

The monitor allows for the adjustment of this sensitivity interval (minimum 0.05 second, maximum 1.0 second) between breaks in order to record individual events. For wildlife monitoring, which these monitors were designed for, a sensitivity interval of 0.05 second would result in the recording of all moving objects including fast moving wildlife such as birds, while adjusting the sensitivity interval to 1.0 second would count only more slowly moving wildlife. The monitor sensitivity interval for this study was determined experimentally to address two important concerns with the use of infrared monitor to count stair and elevator use – accuracy and tampering. In respect to the accuracy of the data, it was discovered that if two or more persons past through the beam without individually breaking the beam, the monitors would record that as an individual event. While there is little that can be done about the potential when using this type of equipment to record traffic to avoid small inaccuracies in the total counts that may occur when occasionally two people walk side by side when using a stair, it could be a problematic issue in an academic building where a large group of students exiting a classroom could possibly be recorded as a single event. Both this issue of accuracy and tampering in the form of hand waving in front of the monitors were addressed by adjusting the monitor sensitivity interval. It was determined in pretests on the stairs and elevators that a sensitivity of .10 second (length of the break in transmission) prior to the recording an event provided that best accuracy to measure small breaks between persons but not record the frequency of most attempts at tampering with the monitors from hand waving. Pretests were conducted to measure accuracy. Equipment was installed on the main atrium stair in the GTCOA and GTARSC buildings. Stair use was measured by both equipment and visual observation for three half hour periods at different times of the day. Accuracy was calculated at 96.3% over the six sets of pretests. The accuracy of elevator use was also a potential problem due to the limited operational room within the elevator cabs.

The accuracy of the elevator counts were more influenced by the placement and the equipment and signage, and after several experiments to develop a final protocol for the elevator equipment installation, three 20 minute pretests sessions, in which the investigator rode the elevator to visually counted elevator use, and compare against the equipment values indicated a 93.8% accuracy rate for elevator counts.

The dependent variable of this study, the percentage of total building vertical circulation attributed to each stair or elevator in their building was calculated based on the five-day accumulative totals for all stairs and elevators in the building. Daily totals for each stair and elevator in the study and their percentage of total building vertical circulation is provided in Table A.1 in Appendix A.

Approval for the use of human subjects in this research project was required and received by both the Georgia Institute of Technology Office of Research Compliance

Institutional Review Board and the Ryerson University Office of Research Services Research Ethics Board.

5.3 Variables of the Physical Environment

In the remainder of this chapter, a set of physical environmental variables which operationalize the constructs of the five themes of the thematic framework for stair use will be presented and discussed. A list of the physical environmental variables described in detail in this section is listed in Table 5.1.

In the survey of building users presented in Chapter 4, 90% of all survey participants identified some aspect of convenience as their reason for route choice. The three most frequently identified reasons: Fastest route (distance), Shortest route (time) and Most connected to other stops made, are distributional relational and spatial aspects of the building users' travel activity within the building layout and may be highly correlated. This section will describe 20 physical environmental variables. The relatively long list reflects the exploration aspect of this study. Each thematic factor of the framework has been defined by multiple constructs. In some case these constructs have been operationalized by multiple variables. In addition, several of the operationalized variables included in the study are alternative measures of the one construct. While consideration has been given to avoid or acknowledge issues of possible colinearity between variables, it is expected that several of these measures may have some correlation with each other. The analysis of each variable's relationship to stair use and the issue of colinearity amongst the variables will be discussed in Chapter 6.

Table 5.1 List of Variables related to Voluntary Stair Use included in the Study

Variables		Operational Definitions
Convenience		
	Proximity	
		Travel Distance between Stair & Closest Entrance
		Travel Distance from between Stair & Elevator
		Travel Distance from Most Integrated Paths
	Distribution	
		% of Total Building Occupant Load served by each Stair
		% of Total Building Area served by each Stair
	Accessibility	
		Physical Accessibility
Legibility		
	Visibility	
		Area of Stair Isovist
		Area of Interior Vertical Exposure
	Imageability	
		Stair Type
	Intelligibility	
		Number of Turns from Closest Entrance
		Number of Turns from Most Integrated Path
Aesthetic		
	Setting Appeal	
		Views
	Stair Appeal	
		Stair Articulation
Comfort		
	Gait Compatibility	
		Riser Height
		Tread Depth
		Tread Riser Ratio
	Exertion Compatibility	
		Maximum Number of Steps between Landings
	Social Operational Compatibility	
		Stair Width
Safety		
	Surveillance	
		Minimum Illumination (ftc)
	Maintenance	
		Maintenance Level

5.4 Convenience Variables

Three constructs of Convenience designated as Proximity, Distribution and Physical Accessibility, were identified to measure aspects of relational, distributive and physical aspects of this theme. The following sections identify and explain the measures of the operationalized variable of each construct.

5.4.1 Proximity

Proximity variables address the relationship between stairs and specific important points of reference related to travel within all multi-story buildings: the entrance, the elevator and the most integrated paths of travel within the building system.

5.4.1.1 Travel Distance from Closest Entrance

Building entrances provide the primary point of orientation for most building users and the proximity of stairs to building entrances may influence stair use. Although stairs in the building act in some way as a means of egress from the building, many of the exterior doors of fire stairs are not intended or operated as a means of building entry. In some cases, exterior stair doors operate as exit only and entry is restricted due to the absence of exterior building door hardware or the installation of door locking hardware. In other instances the orientation or location of exterior doors at stairwells in areas without pedestrian traffic diminished their usability as a building entrance. In this study, the main points of entrance(s) used by the building’s occupants were identified.

Distance from nearest entrance is the measurement of the distance (in feet) of the shortest route devised of straight line segments extracted from computer-generated building floor plan of the subject building from the center line of a entrance door (as identified above) to center line of the stair door or when no door exists, the first step of stair flight.

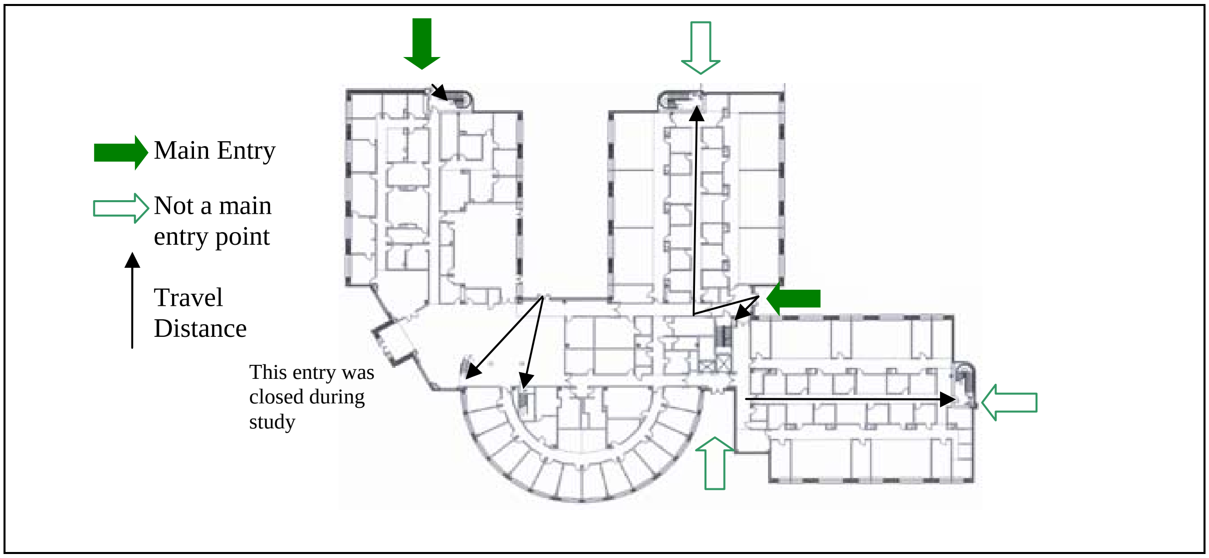


Figure 5.2 Plan indicating Travel Distance of Main Entrances for the Building GTIBB

5.4.1.2 Travel Distance from between Stair and Elevator

Previous stair research studies examined the role of motivational signage on increasing stair use. Many of these studies placed signage where stairs were in close proximity to mechanized alternatives such as elevators and escalators. In these studies, increased stair use is most often based on diverting those who would otherwise use the adjacent elevator/escalator. The convenience of a voluntary selection of any stair in a building may be influenced by its proximity to the elevator.

The travel distance between a stair and the elevator is the measure of the distance (in feet) of the shortest route derived of straight-line segments extracted from computer-generated building floor plan of the subject building between the center lines of the stair or elevator door (Figure 5.3). When no door exists at a stair, the centerline of the first step is used as the reference point. In buildings were there are two adjacent elevators, the measurement is taken from the centerline of the elevator door closest to the subject stair.

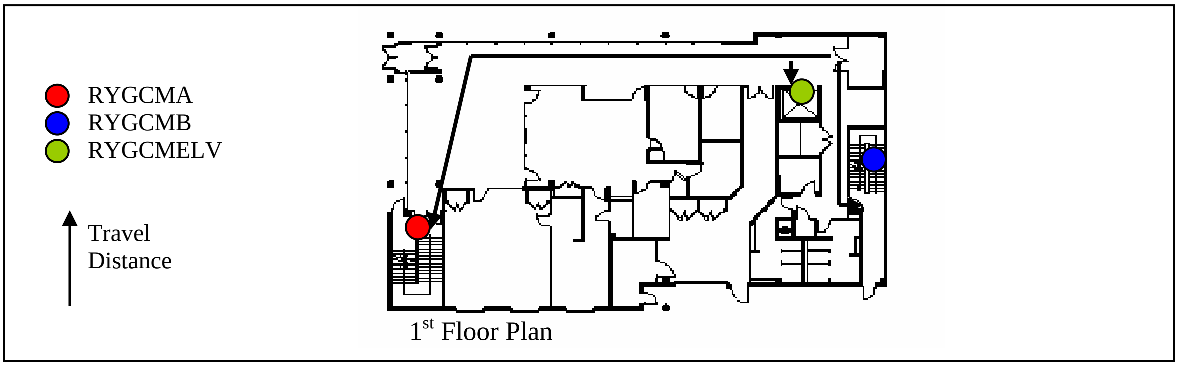


Figure 5.3 Plan indicating Travel Distance between Stairs and Elevator for Building RYGCM

5.4.1.3 Travel Distance from Most Integrated Path

Space syntax techniques use a topological basis for defining space by reducing the complexity of the built environment into discrete spatial units which allows the analysis of the patterns of human relationships in terms of domain, movement, access, control and hierarchy of spaces within a system such as a building or urban environment (Hillier & Hanson, 1984: Hillier 1996; Peponis & Wineman 2002). Space syntax techniques provide a means to quantitatively measure and graphically map the relationship between spatial units within a system by the use of convex and axial mapping. The following is a brief explanation of these two mapping techniques. Convex maps abstract the built environments into distinct spatial units in two dimensions by partitioning the plan of complex room layouts into convex polygons. Axial maps provide a means to understand the way which people move between spaces in a spatial network. Spaces can be represented by the arrangement of convex polygons (spaces) which comprise a complex spatial system. This representation is known as a Convex Map. An axial map is produced by overlaying lines that reflect the structure of movement between the convex polygons. The technique utilizes the convex map by laying down the longest straight line that passes though at least one threshold between two adjacent convex spaces. Axial mapping of a complex system such as a building has been found useful in translating spatial relationships into mathematic values and relations and subsequently their graphical representations.

One such relation that can be calculated is Syntactic Asymmetry (RRA real relative asymmetry) or ***integration***, which shows a tendency to correlate with the distribution of population within an urban setting (Hillier 1996). Integration has been best explained in this manner: "RRA is calculating for each space by calculating the average depth of each node from all other nodes in the graph. This mean depth is then used to compute a number called relative mean depth or relative asymmetry RA which is the mean depth express as a fraction of the maximum possible range of depth value for any node in a graph with the same number of nodes as the system. Integration RRA is a ratio of the RA value of the nodes of the given system and the RA value of the central nodes across its level and so has been found to represent a more realistic benchmark for comparing spatial settings of different size. Integration values are the inverse of RRA (1/RRA) therefore higher integration values of nodes indicate that the node is less deep on an average from all other nodes, in other word that is more integrated into the spatial system (Bafna, 2003)". Integration therefore can be expressed as a numeric value or can be represented graphically by coding the relative values of axial lines on an integration plan. Integration plans use a graphical hierarchy of color to represent the relative hierarchy of integration values within the building system. Axial lines are indicated in a color palette from ranging from red, pink, mauve, light blue and finally dark blue which represent axial lines in their respective order from highest (red) to lowest (dark blue). Red lines indicate the 10% most integrated paths within the building. In this study, the relationship between the location of stairs and the Most Integrated Paths (MIP) location of stairs will be examined. Research has indicated that people have a tendency to travel along the most integrated paths (Hillier, Penn et al. 1993). It is proposed that the proximity between the most integration paths (depicted as red axial lines on the integration plan in Figure 5.4) and stairs may influence stair use.

The travel distance between a stair and the MIP (most integrated path) is the measure of the distance (in feet) of the shortest route derived of straight line segments extracted from computer-generated building floor plan of the subject building between the stairwell and the nearest axial line designated in red as a MIP within the building. Integration plans for each building are illustrated on the Data Sheets in Appendix B.

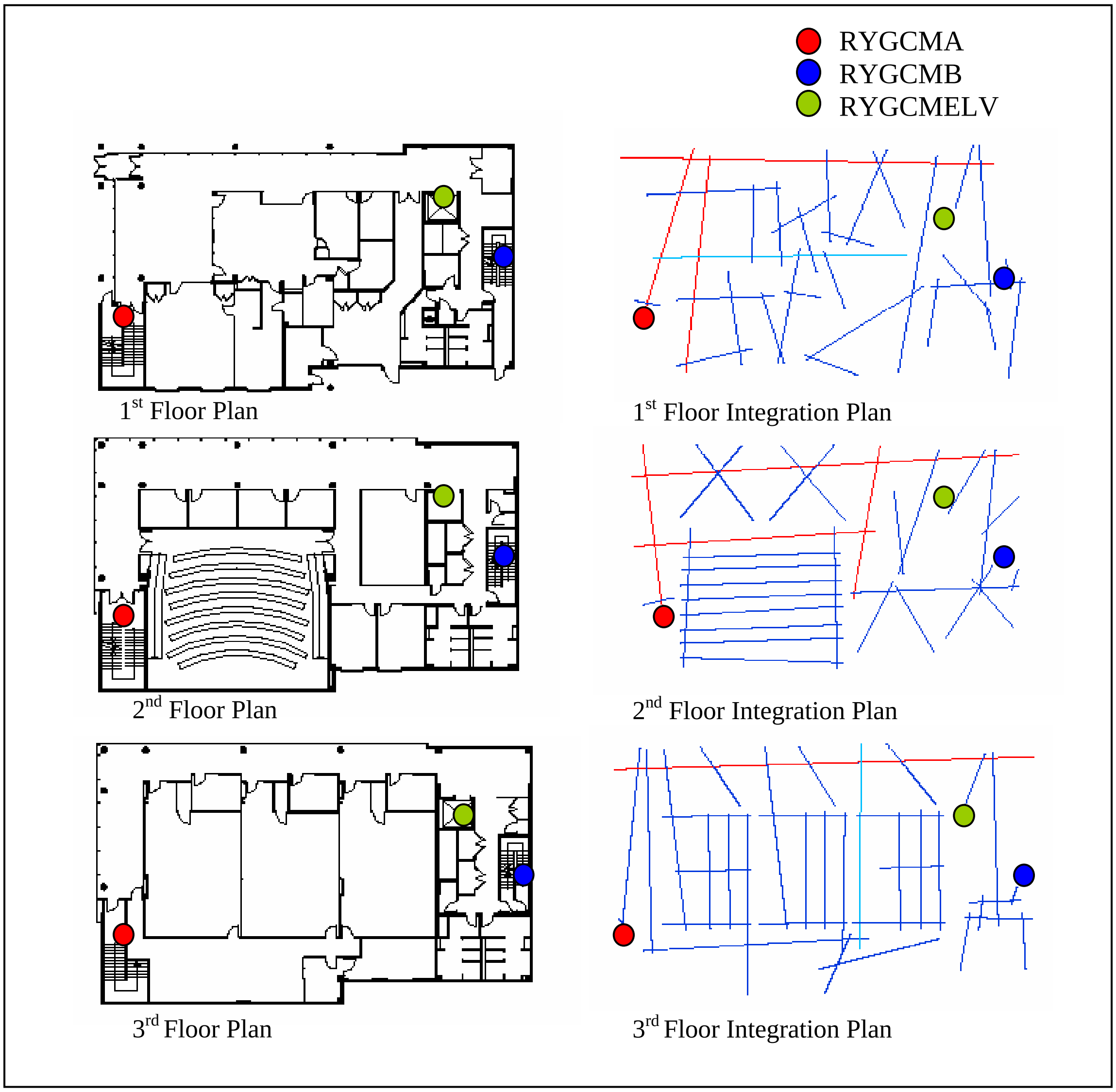


Figure 5.4 **Floor Plans and Integration Plans for Building RYGCM indicating Location of Stairs and Elevators**

5.4.2 Distribution

Distribution variables address the relative distribution of people in programmed activity within the building in relation to the location of stairs. Two alternative measures for distribution variables, both based on building code methods for determining occupant load for determining the sizing for building circulation and exiting, are discussed in this section.

The calculation of the effective area served by each stair has been used in building codes to calculate the total number of people (occupant load) that a building is designed to accommodate. Occupant load is calculated by multiplying the floor area by an occupancy load co-efficient that reflects the accepted concentration of people per square foot within an occupancy type. In buildings of a single occupancy type, such as the educational buildings in this study, the area attributed to each stair provides a simple means of measuring the distribution of people in relation to the location of stairs. However, this is a very general measure that assumes an even distribution of people across the floor plan. An alternative method of measuring distribution, also used in building codes, is to count the number of people a space is used designed for. This method requires the calculation of the number of seating stations with the closest proximity of a stair. This method would reflect a more accurate account of the distribution of sedentary people, especially if the distribution of people is not evenly distributed throughout the floor plate. It does not however measure the distribution of people in movement throughout the building. This study will explore both measures as alternative variables for the distribution of people in the buildings.

5*.4.2.1 Percentage of Total Building Area served by each Stair*

A method of understanding how a building design may affect the convenience is to consider the distribution of stairs within the building. The most frequent reason cited for choice of route in the survey study was the shortest route in terms of metric distance. This suggests that determining the effective area of a stair, which is the area closer metric distance of travel to one stair than any other on a floorplate can measure how stairs are distributed within the layout of the building. Effective areas of stairs are measured as the area in which the distance of travel from any point in the area is closer to the designated staircase than any other. As such the location of partitions separating rooms have an impact on the boundaries of the effective areas. In some instances, the areas of rooms with more than one point of entry are divided between the tributary areas of more than one stair. The areas of openings within the floorplates for atriums where no travel can happen are excluded from these calculations.

The effective area for each stair will be examined both numerically and graphically in the following chapters. In order to account for variances of building size and height in the sample, effective area for each stair can be expressed as a value for the percentage of the total building area, which each stair's tributary area represents. Graphically, the graphical representation of the location of the effective areas of each stair will be utilized in the case study analysis in Chapter 7. Figure 5.5 illustrates an example of the effective areas of stairs in Building GTUAW.

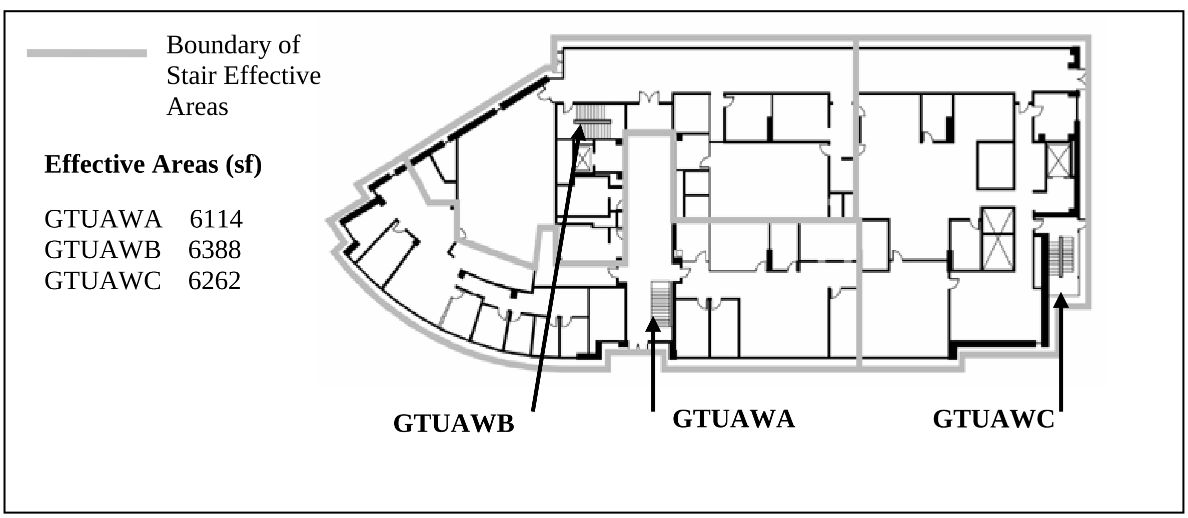


Figure 5.5 Plan indicating Effective Areas of Stairs on the First Floor of Building GTUAW

5.4.2.2 Percentage of Total Building Occupant Load served by each Stair

Another means of understanding how a building design may affect the convenience of using a stair is by considering where people are distributed through the building in relation to stair location. One method is to determine the number of people or the occupant load of each stair within the building. Occupant load is a term used in building regulations, used for determining the provisions of exiting and plumbing facilities in buildings (BOCA, 1999; MMAH, 1999). Within the building code context, occupant load is calculated based one of three methods: multiplying the building area by a co-efficient (persons per area) established for each occupancy classification; number of fixed seats within a space; or by designating and limiting the number of persons a space is designed for. In this study, occupant load will be the measurement of the number of seating stations within each stair's tributary area. Seating stations are defined as the individual seating capacity of workstations, classrooms, laboratories, studios, libraries and the seating in public areas near food or vending services and in lobby areas. The number of stations was determined from a visual inspection and calculation of seating stations within each the buildings.

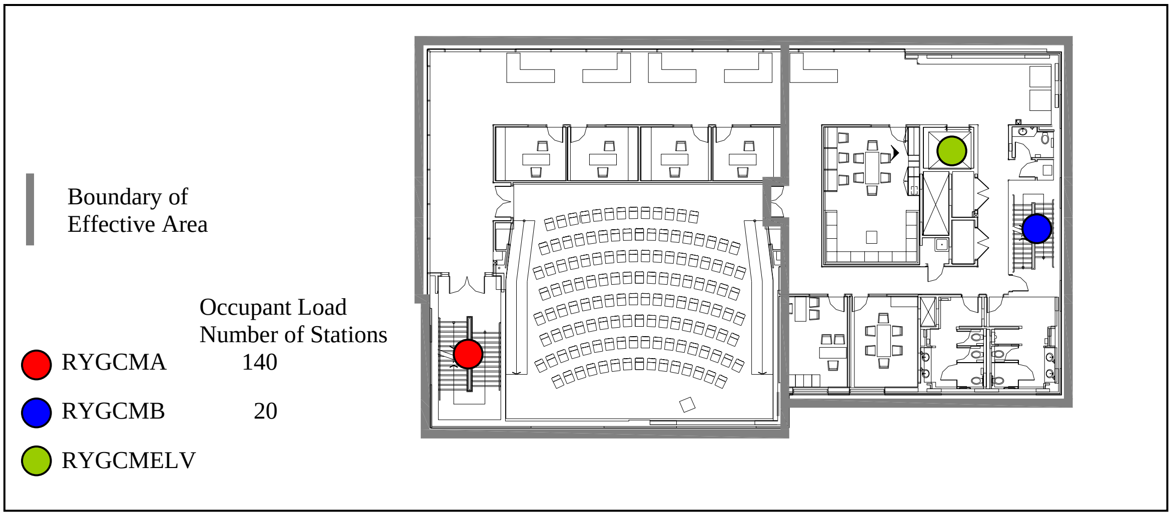


Figure 5.6 Plan indicating Seating Stations used to determine Occupant Load for Building RYGCM

5.4.3 Physical Accessibility

Physical accessibility addresses the ease of entry into the stair environment from other places, which may impact on purposeful travel choices. Although building codes require all stairs to provide public access into the stair from the within the building, accessibility from stairs to other places within the building or into the stairs directly from the exterior of the building can be more restrictive.

5.4.3.1 Physical Accessibility Index

The ease of accessibility for movement between the stairs and other adjacent spaces within and exterior to the building may be an important factor influencing stair use. Some buildings have restricted entry into the exterior of building into stairs or restricted access from stairs into floor areas. Several stairs in this study sample had no entrance hardware on the exterior side of the door that exited directly from the stair at the ground floor to the exterior of the building. Operational decisions based on security concerns are a major factor in determining the accessibility of movement through stairs to other places in the building.

A Physical Accessibility Index was created for this study based on the relative ability and ease of effort to move between the stairwells and adjacent spaces both within the exterior to the building. The physical accessibility index initially considered five possible levels of accessibility for office workers within buildings: No Accessibility, Limited Accessibility, Selective Accessibility, Open Accessibility, and Enhanced Accessibility. Two of these accessibility levels were deemed not applicable to stairs. Stairs, which play an important role in emergency exiting, are not allowed to be inaccessible as a locked mechanical room in a building would be to most office workers. The stairs in this study were not equipped with mechanisms designed to enhance accessibility in or out of the stairwell in the same manner that automatic open holding devices at primary entrances to buildings augment the accessibility into the building. The stair physical accessibility index created for this study identified three levels of access based on the descriptions provided in Table 5.2.

Table 5.2 Stair Physical Accessibility Index

Accessibility Level	**Description**	**Scale**
Limited Accessibility	There is no provision for building entry from the exterior into the staircase and no public or restricted access to floor levels served by the staircase	**1**
Selective Accessibility	Building users have restricted access from the exterior into the staircase or to one or more floors of the building, which the stair serves.	**2**
Fully Accessible	All building users have unrestricted access in and out of the stair and to all floors which the stair serves	**3**

5.4.4 Convenience Variables not considered in this study

Several potential variables were not included in this study. Although the study utilizes the space syntax measures of integration in establishing the point of reference within the building for the Proximity variables: Travel distance between stair and MIP (most integrated path), the discrete values for integration and connectivity of axial lines created from axial mapping were not used. This is primary due to the procedure of examining the building as a set of spaces located on individual floors rather than a single connected system. This method was used to simplify the process of syntactic analysis due the physical complexity of the stair as a form comprised of a complex multi-level set of convex polygons. By examining the buildings as a set of separate floor plates, the axial maps indicate the relationships of axial lines as sub-sets within the greater larger building system. This individual floor plan approach is useful in that it is compatible with the way most architects visualize buildings. The approach provides a simple graphic representation of the most integrated axial lines (MIP) outside the stair environment path, which was used to measure distances from the MIP to the stairs and later in the chapter the number of turns from the MIP to the stairs. This method was chosen for its graphic clarity. An alternative method which would be to draw the building as one connect system by including axial lines that pass through the collection of the convex polygons of the stairwell environment in order to achieve a model of the building as a single system.

5.5 Legibility Variables

The thematic concept of legibility has been categorized by three constructs of environmental cognition: Visibility, Imageability and Intelligibility. Visibility addresses the ability to visually distinguish the presence of an object, in this case the stair or entry into the stairwell. Imageability addresses the identification of the meaning of the object (in this case the stair) with its meaning or intended use. Intelligibility is a term used in this study to measure the complexity of the journey from a specific point of reference to the stair.

5.5.1 Visibility

This study explored two alternative measures of the visibility of stairs within the building: the area of stir isovist and the interior vertical exposure area.

5.5.1.1 Area of Stair Isovist

The results of the survey indicated that visibility of stairs, as an option for route choice may be an important factor in voluntary stair use. Space syntax techniques provide for a means of measuring the visual field of objects. This is achieved by the use of the graphical representation of the horizontal extent of a person's visual field from a specific point of reference plotted onto a building floor plan (Benedikt, 1979; Turner & Doxa, 2001). Properties of the isovist such as the shape, direction and size of axial dimensions and area of the isovist can be used describe and compare the quantity and quality of the visual field(s) within a floor area. Visibility will be operationalized in this study quantitatively as the average area (per floor) of each individual stair's isovist representing the extent that a stair well or stair is visible on each floor of the building.

In this study the stair isovist is generated by plotting on a building floor plan the surrounding area of the stair, which can be seen from any point within the stair. In the case of enclosed stairs, the calculation was generated assuming that the door to the stair was open. Exterior areas were not calculated, resulting exterior stairs GTCOA B and GTCOAC not been included in this measure.

Isovists provide both numeric and graphic data for analysis. The plan area of stair isovist at each floor can be measured to provide total area in square feet of the visual field of each stair. To compensate for differences in the number of stories in the sample, the statistical analysis in Chapter 6 will use the average isovist area of each stair. Graphically, isovist permit the extent of the visual field of the stairs to be mapped onto the building floor plans as indicated in Figure 5.7, which will be used in the case study analysis in Chapter 7.

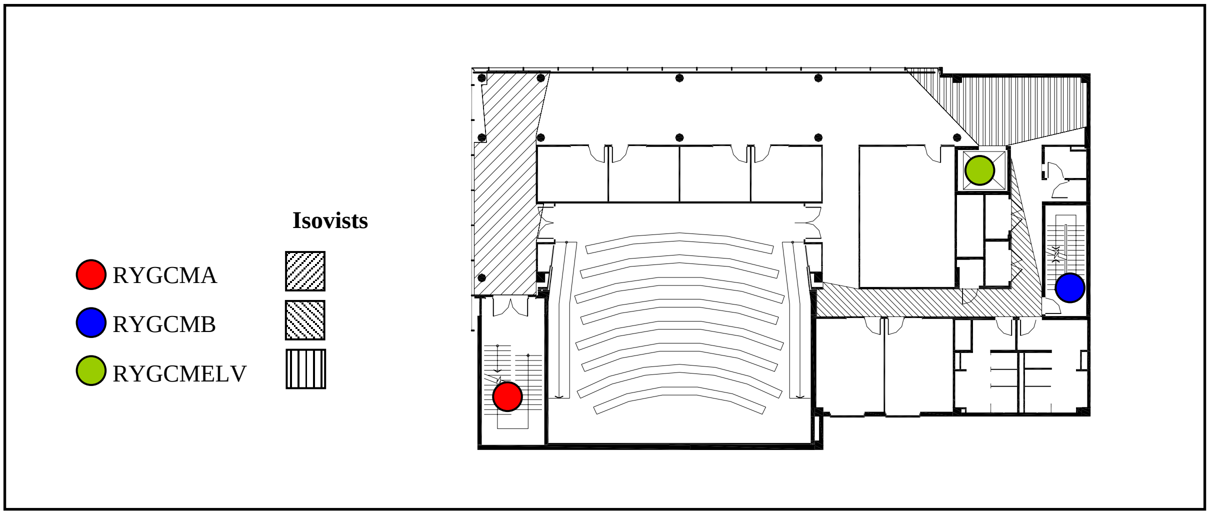


Figure 5.7 Plan of Building RYGCM indicating the Areas of Stair Isovist

5.5.1.2 Area of Interior Vertical Exposure

An alternative method considered in this study for assessing the visibility of stairs was a measure of the visual openness of the vertical surface area of the stairwell enclosure. The area of interior vertical exposure is calculated by measuring the area of the vertical interior surfaces of the stairwell enclosure on the ground floor that is either open to the adjacent interior space or visually accessible through glazing in the walls or doors of the stairwell. Glazing includes safety, laminated or wired glass windows in wall or doors and wall constructed of glass in metal frames, which separate the stairwell from the adjacent interior spaces. The area of vertical interior exposure was determined for enclosed stair based on the condition of enclosure at the time of the measure of stair use. The area of vertical interior exposure for stairs with doors generally in the closed position (due to door closer devices) was limited to the area of any glazing in the doors or adjacent walls. Doors that were propped open or held open with the provision of electronic hold-open devices had interior exposure areas, which included the open area within the dimensions of the doorframe. The area of interior vertical exposure of stairs located in atrium or corridors, which were not enclosed in stairwells, was measured along the open end of the stair stringers from floor to ceiling.

5.5.2 Imageability

Imageability is one of the basic concepts of environmental cognition. Kevin Lynch defined imageability as "that quality in a physical object which gives it a high probability of evoking a strong image in any given observer. It is that shape, color, arrangement which facilities that making of vividly identified, powerfully structured, highly useful mental images of environment"(Lynch, 1960). Lynch's goal was to explore the way that people understand complex environments such as cities. His concepts were based on the notion that people understood their world through the visual domain, that visual recognition initially connected meaning to forms created cognitive maps comprised on environmental images as a means to make sense of their environments. Environmental images are created by the observer through the selection (reduction), and organization (spatial structure or pattern relationships) of discernable characteristics and relationships within complex environments. An environmental image according to Lynch has three components: identity, structure, and meaning. Identity is defined by the distinctiveness and wholeness of objects or features from others. Structure refers to the spatial or pattern relationship of the object to the observer or other objects. Meaning refers to the way that the object is significant, symbolic, or represents value in either a practical or emotional sense.

The notion that people create mental maps of their urban environments by visual recognition of its many unique features may be useful in examining the role that the distinctive forms of stairs assume within the realm of the building environment. As discussed in Chapter 1, variety in the design attributes and form of stairs have been stratified by response to regulation and economic restriction which tends to enclose, conceal, and provide minimum levels of articulation to those stair intended primarily as a means for emergency exiting and the creation of stairs as articulated forms and construction intended to present the stair as an important feature for vertical access and movement through the building.

5.5.2.1 Stair Type

In most buildings there is one stair, which is distinctively more visually articulated in its size, form construction, and material finishes than any other in a building. These stairs have sometimes been referred to as grand staircase. Grand stairs may convey, through their distinctiveness and wholeness of form and expression, the message to building users that this is a stair designed for their vertical circulation throughout the building. Many of these stairs are located within large lobbies or atrium spaces in the building and have high visibility (which suggests some correlation between the visibility (stair isovist) and stair type (grand stair)).

This study will measure imageability by classifying stairs types. Stairs were classified by its distinctive form and aesthetic properties as being either a *grand stair* within a building (Grand Stair = 1) or not grand (Other Stairs =0). It is noted that not all building have grand stairs. In building RYGCM neither of its two stairs was significantly more articulated in material and construction than the other. Stairs that were determined to be grand stairs by their size, form construction and material finishes were GTCOAA, GTELA, GTIBBA, GTUAWA, GTIBBA, RYARSCA, RYINTA, RYMONB and RYENGA.

5.5.3 Intelligibility

Intelligibility is a space syntax term that addresses the predictability of the global structure of an environment from a reading of its local properties. In this study intelligibility of stair locations within the buildings will be analyzed by considering the local property of a stairs axial depth or the angular re-orientation during travel from the closest segment of the MIP (Most Integrated Path).

5.5.3.1 Number of Turns from Closest Entrance

The ability for people to understand complex environments can also depend on complexity of movement through an environment such as the number of times a person is required to reorient their movements to get form one destination to another. This study will measure the intelligibility of the routes to stairs calculating the axial depth of the stair. Axial depth refers space syntax measure of the spatial relationship between spaces. Axial depth is counting the intervening number of spaces between two spaces. Figure 5.8 illustrates that this can also be measured by counting the number of turns required for more from one destination to another destination. The survey conducted in Chapter 4 indicated that many people chose to use the stair closest to their entry point into the building. Based on this observation, one measure of intelligibility that will be determined by the fewest number of turns required during the journey from the closest building entrance (as defined in *5.4.1.1*) to the stair as illustrated in the example in Figure 5.8

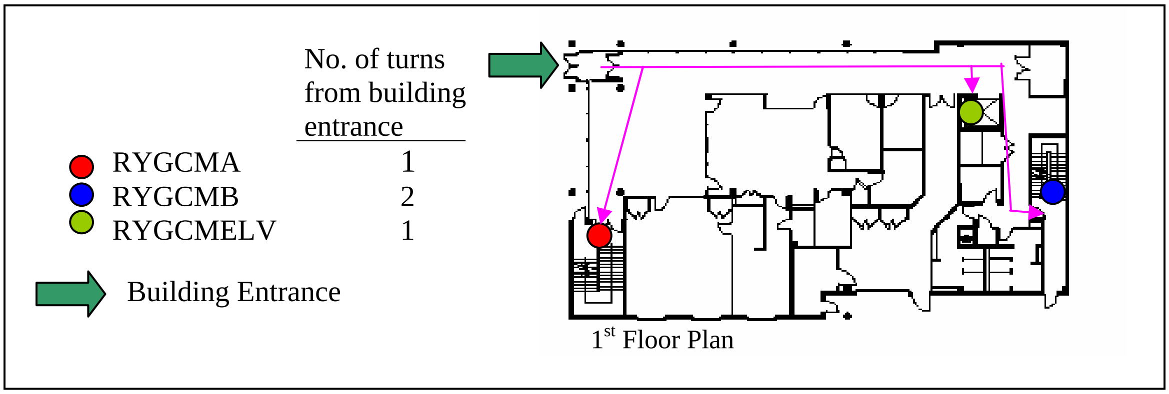


Figure 5.8 Plan of Building RYGCM indicating the Number of Turns from the Closet Building Entrance

*5.5.3.2 Number of Turns to MIP (Most Integrated Path***)**

While many multi-level trips in buildings are the result of travel either starting or ending outside the building, there was considerable travel observed in the 10 buildings between spaces within the buildings as well. This suggests that intelligibility should also be measured as the relationship between a local spatial attribute of the stair and the global spatial structure of the buildings. Therefore, this study will also examine the intelligibility of the routes to stairs by the number of turns required during the journey from the closest most integrated path (described in *5.4.1.3*). This variable measured by calculating the number of turns of any angular value from the axial lines designated as the MIP (Most Integrated Path) and the entrance to the stairwell (Figure 5.9), or where the stair is not enclosed, to the first step of the stair .

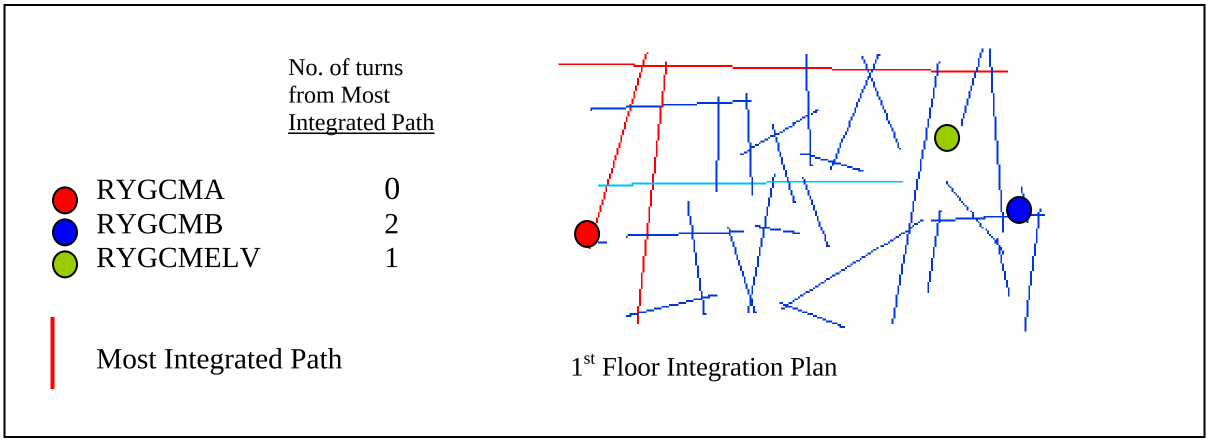


Figure 5.9 **Integration Plan of Building RYGCM indicating the Number of Turns from Most Integrated Path**

5.5.4 Legibility Variables not considered in this Study

There has been considerable attention in previous stair use studies in exploring the role of motivational signage as a possible environmental intervention to increase stair use. The presence of signage demarcating the presence or encouraging the use of stairs was not included in this study. All stairs in this study complied with building code regulations requiring an illuminated signage with the word EXIT clearly visible at each exit stair door. However within the study buildings, no other signage identifying or encouraging stairs or an elevator was present.

5.6 Appeal Variables

Several studies have presented a link between the appeal of the physical environment and participation in physical activities such as walking and cycling (Pikora, Giles-Corti et al. 2003) or supports a user's satisfaction (Kaplan, 2001) with built environments. In Chapter 4, survey participants identified the presence of interesting views as a reason for their choice of route. Appeal is a highly subjective and complex measure, which both may differ between individuals, may also be influenced by cultural norms within populations. This study does not venture into an assessment of the relative qualities of subjective visual or sensory appeal. In this study the broad concept of Appeal was defined by two constructs: Setting Appeal and Stair Appeal.

5.6.1 Setting Appeal

This study operationalized the appeal of the setting which a stair is located by one variable: View from the stair.

5.6.1.1 View from the Stair

To examine the effect of views from the stairs, a basic scale of the visual interest of view settings from stairs was developed for analysis. Views were classified into four types of view settings the composition and relative vista of the view from the stairs. Values for the view from the stair increase with the scale of the visual field and complexity of the physical setting as indicated in Table 5.3. The lowest value (Value = 0) is assigned to the absence of a view. The values assigned to the settings increases with the provision or opportunity provided in the setting for the observation of natural landscape and interesting human activity. The highest value (Value = 4) is assigned to expansive views that are settings for human activity (such as atriums) or the views of natural environment (scenic landscapes and courtyards). Stair views were evaluated by a panel of architects (Note 3) from photographs of all the views evident from the staircase and assigned an ordinal value.

Table 5.3 View Setting Index

View Designations	Value
No view outside of stair provided	0
View of interior wall of adjacent space or exterior wall of building or adjacent building only	1
View of streetscape including view of exterior buildings and vehicular traffic	2
View of interior and exterior people oriented spaces and scenic landscapes	3

5.6.2 Stair Appeal

This study operationalized the appeal of the stair as an object as an object of interest and admiration by one variable: Stair articulation.

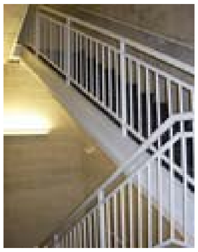
5.6.2.1 Stair Articulation

The variable Stair Type (5.5.2.1) utilized a dummy variable (grand stair =1) for measuring stair imageability, which addresses the wholeness of a stair's identity, distinctness and articulation. The measure of comparative qualities of the appeal of a stair form is a problematic task largely due to the difficulty in establishing generally accepted and objective definitions of appeal. For this study, it was determined that the provision of a relative articulation of the stair form and finishes within the stair environment may provide some insight into the role of appeal and stair use. As such, stairs were ranked based on a simple comparative visual analysis of form and finishes based on a basic standard selected from the sample of a stair that meets the description of each stair articulation type as illustrated in Table 5.4. A panel of three architects[3] examined photographs of all 38 stairs and

[3] The panel who evaluated both Setting Appeal and Stair Appeal was comprised of John Robulack, Maria Krendler and Gayle Nicoll

assessed each stair's articulation in accordance with the descriptions of stair articulation listed in Table 5.4.

Table 5.4 Stair Articulation Index

Stair	Description	Examples	Value
Basic Stair	Basic stair form and construction with minimal applied finishes and details. Common stair construction components utilized in either painted steel, poured concrete or precast concrete (painted). Walls and ceilings are either unfinished concrete block or painted drywall. Non-slip vinyl or painted stair treads	Stair GTGCMB 	**1**
Enhanced Stair	Stairs may have one or more the following features: Interesting color, features, finishes applied to basic stair form or stair enclosure; Sculptural (non-rectilinear) forms such as curved stairs or landings; Enhanced craftsmanship in the detailing and manufacturing of standard stair elements.	Stair GTMARCB 	**2**
Articulated Stair	Stairs may have one or more the following features: Interesting, distinctiveness and unique detailing of the form, finishes and elements of the stair and/or its surroundings.	Stair GTELA 	**3**

5.6.3 Appeal Variables not considered in this Study

This study has limited its investigation of appeal in consideration of the complexity and subjectivity of defining and measuring qualitative aspects of appeal of specific features. In addition, the presence of art that has been previously cited as influencing stair use in a previous study (Kerr, 2001) was not included as only three stairs in the study contained artwork or posters within the stairwell.

5.7 Comfort Variables

In this study, aspects of human comfort has been categorized by three constructs: Gait compatibility, Exertion compatibility, Situational Compatibility

5.7.1 Gait Compatibility

There is a wide variability within most workplace populations in the size, weight, strength, coordination and proportions of the human body of potential stairs users. Most healthy people are resilient in their ability to adjust to differences in the dimensions of risers and treads on different stairs. However, people are often placed at a risk for injury from falls when required to adjust to variances in riser height or tread depth within the same flight. Three measures of gait compatibility were identified for consideration in this study: riser height, tread depth, and the riser/tread ratio.

5.7.1.1 Riser Height

Riser height is regulated by building codes, which establish a minimum and maximum height for stair risers (example: 4 7/8” minimum and 8 ¼” maximum (MMAH, 1997)). All variance in riser height in the sample was in compliance with each building’s the relative building regulations. The riser of a stair is the vertical differential between treads of a stair Riser height is measured as the vertical dimension from the edge of the nosing of one step to the nosing of the adjacent step as illustrated in Figure 5.10.

5.7.2.2 Tread Depth

The tread of a stair is the horizontal surface of the step. Tread depth is measured as the horizontal dimension from the edge of the nosing of a step to the vertical surface of the riser when present as illustrated in Figure 5.10. The tread depth of the wedge–shaped treads of spiral-shaped stairs (GTIBBA) is measured as the depth at the center of that tread. Tread depth is regulated by building codes which establishes a minimum tread depth of 10" and maximum tread depth of 14" (MMAH, 1997).

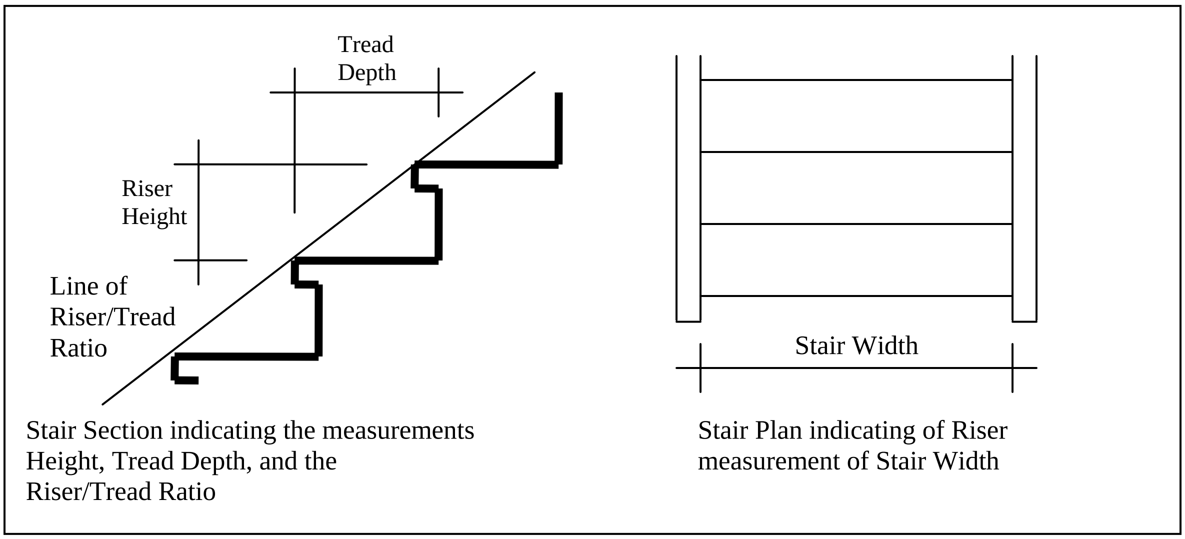


Figure 5.10 Measurements of Comfort Variables: Risers, Treads and Stair Width

5.7.2.3 Riser/Tread Ratio

The ratio between riser and tread dimensions has been cited as an important safety in stair design (Templer, 1992) but has not been linked to the choice of stair use. The ratio between riser and tread dimensions, which is regulated by building code, establishes a maximum angle or ratio for stairs for general use (service stairs may be steeper). The ratio of riser height and tread depth is the expressed as a numeric value of riser height divided by tread depth.

5.7.2 Exertion Compatibility

It is likely that that people choose to travel on the elevators instead of using the stairs to avoid physical exertion. Indeed, for a certain segment of the population who has physiological conditions related to health and age, stair use is not a practical option for everyday vertical travel. Most people experience also experience limits on their ability to undertake the physical exertion of stair use due to temporary conditions such as fatigue, temporary physical restrictions resulting from sickness or from carrying heavy loads. This study operationalizes the ability of stairs to accommodate physical exertion by one variable: Maximum number of steps between landings.

5.6.2.5 Maximum Number of Steps between Landings

The maximum number of steps between landings is measured as the maximum number of risers between any landings of the stairs. Building codes set minimum and maximum values for the number of steps for between landings by establishing a minimum of 3 risers for any flight of interior stairs and a maximum rise of 12’-2” between floors and landing. This variable is measured by counting the largest number of risers between landing areas in all flights of the stair, as illustrated in Figure 5.11.

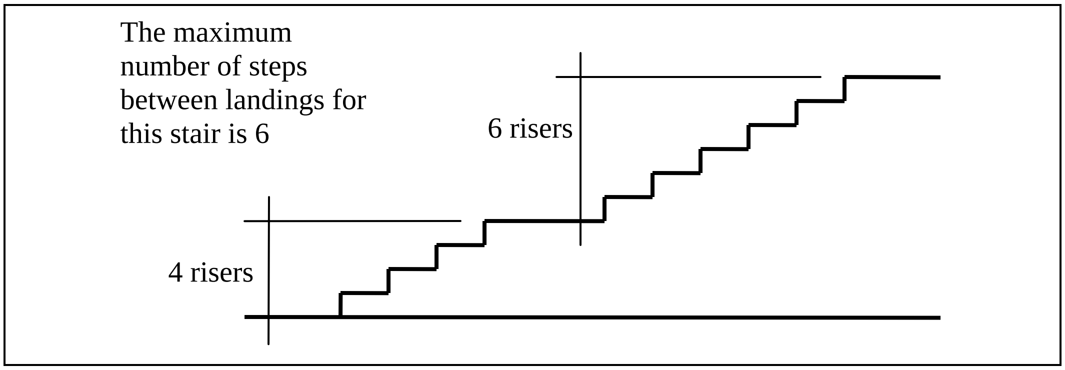


Figure 5.11 Stair Section indicating the Maximum Number of Steps between Landings

5.7.3 Social Operational Compatibility

Social operational compatibility refers the physical aspects of the stair environment that accommodate the social interaction between people. This includes the ability to accommodate travel of more than one person engaged in social interaction, to travel comfortably on the stairs that are being used by more than one person either (traveling in either the same or opposite direction) and not engage in social or physical interaction. Social operational compatibility was operationalized by the width of the stair.

5.7.3.1 Stair Width

Stair width is usually determined based on occupant loads defined by building code regulations. The aggregate width of all stairs on a single floor is determined by multiplying the maximum occupant load of the area served by 5/16” per person (MMAH, 1997). The minimum width of stairs is regulated by building code. For example for stairs that serve more than 3 stories above grade the minimum stair width is 3’- 7” and for stairs serving less than 3 stories above grade the minimum stair width is 2’-11”. Stair width is measured as the horizontal dimension of the stair tread between the either stair stringers, balustrades or walls that support or contain the stair tread as illustrated in Figure 5.10.

5.7.4 Comfort Variables not considered in this Study

Comfort variables not considered in this study were one of the identified issues of gait compatibility: riser or tread dimensional uniformity within a flight; and two issues of situational comfort: shelter from the exterior environment and stair/elevator vibrations/operational stability. These variables were not considered in the study due to a lack of variability within the sample of buildings. Only two of the buildings 43 stairs were exterior stairs (GTCOAB and GTCOAC) and no extraordinary vibration or deflection was observed in the stairs or elevators in the study.

5.8 Safety Variables

Stair environments have been identified as dangerous places (Templer 1992) due to the risk of injury or even death from falls on stairs. It needs to be recognized that there is a risk for injury in any physical activity. This study will focus on two aspects of safe stair environments. One issue considered is the impact of poor operational visibility on natural surveillance illumination which could impact on the ability of a stair user to assess through natural surveillance the stair environment for potential hazards which could contribute to falls or slips on the stairs. Another construct of safety considered in this study is the degree in which stairs are maintained to avoid potential hazards due to use, wear and tear or intentional damage.

5.8.1 Natural Surveillance

This study operationalized the ability to conduct natural surveillance to assess the safety of a stair environment with one variable: Minimum staircase illumination.

5.8.1.1 Minimum Staircase Illumination

Operational visibility within the stair environment may impact on stair safety and the choice of stair use. Measurements of staircase luminance were recorded during the 5-day period in which stair use was monitored for stair use. Stairs, which relied entirely on artificial lighting, were measured twice: during equipment set-up and equipment retrieval on the first day of stair use monitoring. Stairs which were also illuminated with natural lighting were measured four times: during equipment set-up and equipment retrieval on the first day of stair use monitoring and two additional days (day 3 and 5) at noon.

Staircase luminance was measured using a Type 214 light meter manufactured by General Electric. Measurements were taken at the center of the bottom and top step of each flight and at the center of each landing on the stair flight being monitored. The meter was placed approximately one foot from the surface of the tread or landing. Care was taken not to block light on the meter from either artificial or natural light sources. The minimum staircase luminance is the lowest staircase luminance readings taken at any of the readings taken from the first and top step and the stair landings for each stair.

5.8.2 Maintenance

This study operationalized the maintenance of stair environments with one variable: Maintenance level.

5.8.2.1 Maintenance Level

Although CPTED principles suggest a mutually dependent relationship between poorly used areas of the environment and unsafe conditions due to poor operation maintenance, increased likelihood of hazards and crime activity, there has been no known study that has linked maintenance levels to stair use in buildings. This study created a maintenance level index comprised of the assessment of three factors: cleanliness, operational wear and intentional damage described in Table 5.5.

Each stair and elevator in the buildings was visually assessed by the author for each of the three maintenance categories. An ordinal values between 0 and 3 was assigned for each category and then totaled for a combined maintenance value for each stair. An assessment of zero in any category recognized a maintenance issue that prevented use of the stair or elevator. No stairs or elevators were non-operational during the monitoring period of the study.

Table 5.5 Maintenance Level Index

Maintenance Level		Value
Cleanliness	Presence of dirt, refuse or objects which prevents use of the stair or elevator	0*
	Visual dirt, dust, spills, residue, refuse on any surfaces Presence of dirt, refuse or objects over a one day period	1
	Visual presence of dirt, dust, spills, residue or objects that would be expected within the operations of a one day period	2
	No visual evidence of dirt, dust, spills, residues on any surfaces	3
Operational Wear	Major visual evidence of mechanical and chemical abrasion or breakage that ceases stair or elevator operations	0*
	Major visual evidence of mechanical and chemical abrasion of surfaces components;	1
	Minor or incidental wear of the surfaces; Wear of components that may cause minor operational performance	2
	No visual evidence of wear on the surfaces All operational components in good working order	3
Intentional Damage	Evidence of intentional damage or vandalism to stair or elevator that ceases stair or elevator operations	0*
	Evidence of intentional damage or vandalism of the surfaces or components including application of graffiti	1
	Evidence of minor damage that may have been purposely caused	2
	No visual evidence of graffiti, intentional damage to surfaces or operational components	3
Maintenance Index Score is the accumulated scores of 1 to 3 assigned in consideration of the cleanliness, wear and vandalism scales. A score of 0 in any of the categories indicates that the stair or elevator is non-operational due to one of the maintenance criteria and an overall score of 0 is to be assigned.		

5.8.3 Safety Variables not considered in this Study

This study was performed on two university campuses: one in Atlanta, Georgia, U.S.A. and the other in Toronto, Ontario, Canada. Care was taken to assess how the two distinct sets of environmental conditions, expectations, preparation and maintenance by inhabitants may influence stair use. To address the differences in climatic conditions, stair counts were conducted in Canada during the fall of 2004 when winter snow and ice conditions would not impact on building use during this study. Climatic conditions were not recorded during the study.

5.9 Chapter Summary

This chapter identified the dependent variable, stair use, and 20 physical environmental variables that operationalized the constructs of the five themes (Convenience, Legibility, Appeal, Comfort and Safety) of the thematic framework presented in earlier chapters. These variables will be used in statistical analyses to examine which independent variables are associated with stair use with a cross sectional study of ten academic buildings.

CHAPTER 6:
STATISTICAL ANALYSIS OF THE KEY SPATIAL VARIABLES ASSOCIATED WITH STAIR USE IN THE TEN BUILDINGS

In this chapter, the relationship between stair use in 3 and 4 story academic workplace buildings and the 20 physical environmental features identified within the 5 theme (Convenience, Legibility, Appeal, Comfort and Safety) framework and operationalized in the previous chapter will be examined using statistics analysis techniques.

Four main outcomes of this analysis are discussed in this chapter. First is an examination of the variability within the selected physical environmental variables that was present in sample of academic buildings. This analysis will be used to understand the range of physical attributes that can be expected in existing design practices and to eliminate from further discussion in this study, those variables that had insufficient variance for analysis. The second outcome comprises a set of bivariate regression analyses that test the research hypotheses introduced in Chapter 2, These hypotheses will examine the relationships between individual physical environmental variables operationalizing the constructs of convenience, legibility, appeal, comfort and safety of stairs within buildings and stair use. The third outcome of this chapter is an analysis of the colinearity amongst the measures of the study's variable. The fourth outcome constitutes the identification, using multivariate regression, of a small number of key variables that may, by inference, most characterize the physical properties associated with stair use in workplace buildings.

This chapter includes:

6.1 The Data Set – A Sample of 10 Academic Buildings-in Use

Ten academic program buildings, five on the campus of the Georgia Institute of Technology in Atlanta, Georgia and five on the campus of Ryerson University in Toronto Ontario were chosen for this study. These buildings were selected from an inventory of available buildings on each campus based on the following shared criteria:

- Buildings are 3 or 4 stories in building height
- Buildings accommodate academic programs where the majority of building users, comprised of students, faculty and staff, spend the majority of their day within the buildings and are unlikely to use other buildings within the study.
- There is a diverse range of specialized functional spaces within the buildings, which generally requires building users to make multiple trips through the building each day.
- Stairs and elevator(s) are the only mode of vertical circulation in the building (no escalators).

The five buildings selected from the campus of Ryerson University represent the entire inventory of 3 or 4 story academic program buildings on Ryerson University campus. The buildings on the campus of the Georgia Institute of Technology were selected from an inventory of 7 buildings, to optimize the diversity in the physical environments within the study sample. The ten buildings are diverse in their date of initial construction age, ranging from circa 1920 to 2004. Building areas range from 22,000 to 173,000 square feet. The data set of buildings ranges from compact to elongated floor plans, and include cellular office/rooms arranged along public corridors and open plan or interconnected studio and lab spaces; circulation layouts as illustrated in Figure 6.1. Each building contains between 2 to 6 stairs that service floor levels also served by a building elevator. There is also a wide diversity in the physical attributes of stairs and elevators, Measurements of stair use in the ten buildings varies from 40% to 87% of all vertical travel in their respective buildings. Table 6.1 provides a brief profile of the building's attributes.

Table 6.1 Profile of Subject Buildings - Building & Stair Use Statistics

Building ID	Total Number of Stairs	Number of Elevators	Gross Building Area (sf)	Number of Stories	% Stair Use
GTCOA	6	1	166186	4	87.1%
GTEL	5	1	115953	3	87.5%
GTUAW	3	1	59236	3	76.0%
GTIBB	6	2	121713	3	52.6%
GTMARC	5	1	116428	4	66.5%
RYARSC	3	1	57372	4	85.2%
RYGCM	2	1	22115	3	74.3%
RYINT	2	1	34256	4	72.9%
RYMON	2	1	23831	4	39.9%
RYENG	4	2	173117	4	60.8%
Total	38	12			
Mean	3.8	1.2	89021	3.6	70.48
Std Dev					15.72

Measurements of vertical travel in the buildings indicated that stair use exceeded elevator use as the means of vertical circulation in 9 of the 10 buildings. Six of the buildings (GTCOA, GTEL, GTUAW, RYARSC, RYGCM and RYINT) had an overall high level of stair use exceeded the mean value of 70.48% stair use in the ten buildings. Only Building RYMON recorded less stair use (39% of vertical travel) than elevator use. Measurements and descriptive statistics of stair and elevator travel are available in Appendix A.

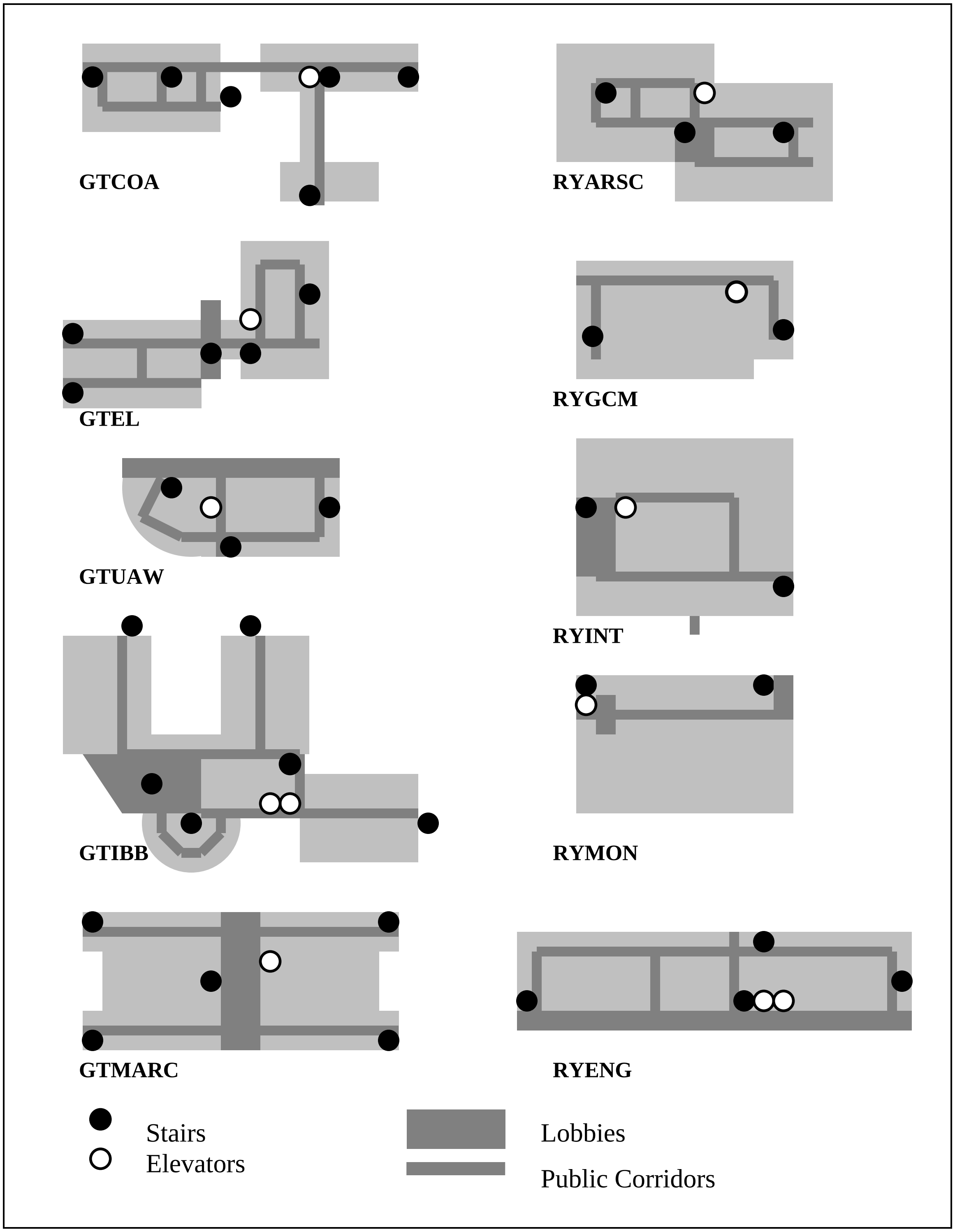


Figure 6.1 Schematic Plans of the 10 buildings of the Data Set indicating the location of Stairs and Elevators within the Arrangement of the Buildings' Circulation Systems.

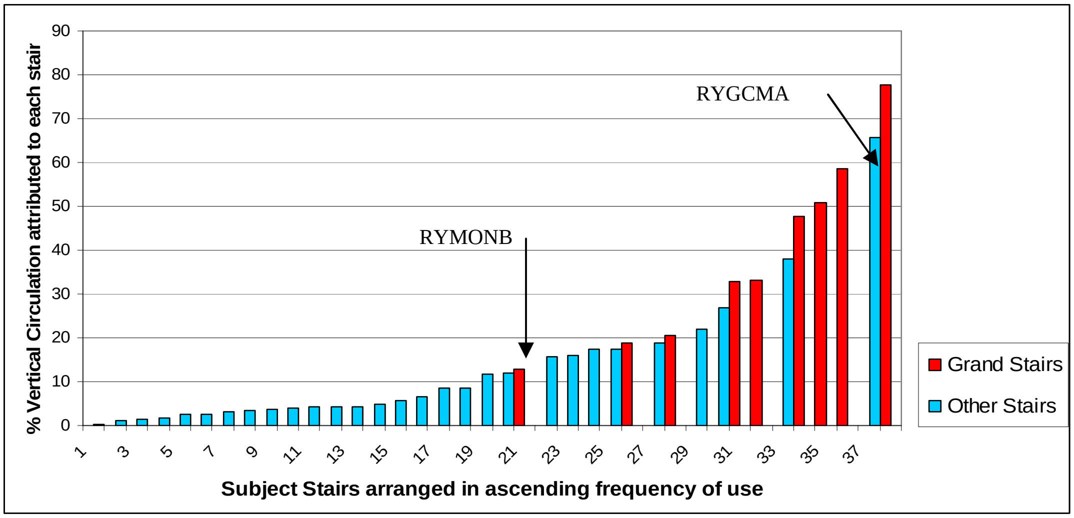


Figure 6.2 Distribution of Individual Stair Use as a Percent of Vertical Circualtion in their Building (Arranged in ascending order of use by stair type)

6.2 Variance Analysis of the Physical Environmental Variables within the Sample of Academic Workplace Buildings

6.2.1 A Profile of the Dependent Variable: Stair Use

Measurements of vertical travel were conducted on the 38 stairs and 12 elevators located within the ten buildings. Only stairs that linked floor levels serviced by elevator access were investigated. A review of the data sample indicated that there was a wide variance within the frequency in which individual stairs and elevators are used. An analysis of the distribution of stair use indicated that 25 of the 38 stairs were used less than the mean stair use of 17.8 %. Thirteen of the stairs were used for less than 5% of the vertical circulation of their respective buildings. The high number of stairs (18 of 38) within the sample that represent less than 10% of vertical circulation within their buildings (Figure A.2 of Appendix A) appears representational of the earlier assertion that while multi-story buildings have numerous stairs, most are not used for everyday travel. However, four of the thirty-eight stairs accommodated more than 50% of vertical circulation in their buildings. Nine stairs outperformed measured elevator use within their own buildings. Six of the highly-used stairs could be classified as grand stairs; stairs which are highly articulated, open to their surrounding environment and located within primary orientation nodes with the buildings. The stratification between grand stairs and all other stairs is evident in Figure 6.2 which plotted the distribution of stair use amongst the 38 stairs in ascending order. Grand stairs generally account for the higher frequencies of stair use in the data set. Figure 6.3 indicates two outliers to this observation: Stair RYMONB, which receives the least use of all the grand stairs, and Stair RYGCMA which receives the most use of all non-grand stairs. Two grand stairs (RYMONB and GTELA) receive relatively modest use in relation to other stairs and elevators within their buildings. Grand stair RYMONB (12.8%) is outperformed by the other stair in its building (RYMONA at 27.0%) and grand Stair GTELA (18.9%) has similar performance values as other stairs GTELD (17.5%) and GTELE (15.6%). The frequency of stair use measured amongst the 38 stairs of this study appears to provide a data set with a robust variability.

6.2.2 A Profile of the Independent Variables

There are 20 independent variables of the physical environment (described in Chapter 5) used to operationalize the constructs of the thematic framework. This section provides a discussion of the variability found within each variable to better understand the nature of the variable data, and to eliminate from subsequent discussions in this study, those variables where there is insufficient variance in the sample. Histograms and descriptive statistics are provided for each of the individual variables in Appendix A. In conformance with the structure of other discussions in this report, the variables will be discussed within their thematic factors.

6.2.2.1 Convenience Variables

This section examines, within the data set, the variance within the operationalized variables of the constructs of convenience: proximity, distribution and accessibility.

Proximity was operationalized by three variables, which measured the relative position between stairs and three key points of reference within the building. Although most stairs in buildings are designed for exiting purposes and include a doorway at ground level, many of these doors are not used as an entrance into the building. Although 25% of the stairs are within close proximity (38 feet) of an entrance, the distribution of this variable's data (Figure A.3) indicates that there is a wide variance in the distances between stairs and the closest entrance to the building ranging from 3 feet to 281 feet, with a generally well distributed set of values within the range of 3 feet to 180 feet for 34 stairs.

The descriptive statistics illustrated in Figure A.4 indicates that the distance between the elevator and individual stairs is also widely and evenly distributed between a close proximity of 6 feet to a maximum of 281. In the data set, of the ten stairs located closest to the elevator within their building, six have been classified as Grand Stairs (GTELA, GTMARCA, GTUAWA, RYARSCA, RYINTA and RYENGB) and the remaining four as non-grand stairs (GTCOAD, GTIBBC, RYGCMB, RYMONA). This data set provides a degree of variance in what may best be described as the architectural intention for stairs located adjacent to elevators. Stairs are either presented as an equitable and imageable alternative (grand stairs) mode for vertical circulation with the elevators or as an ancillary mode (non-grand) in respect to the elevator use.

Most stairs in the ten buildings (29 of 38) were located within 25 feet of the space syntax measure: Most Integrated Path (MIP) as indicated Figure A.5. This reflects that all ten buildings were primarily organized to locate functional spaces along a series of public corridors where the MIP is often but not always located. Twenty-five feet is a relatively small distance for travel within a building (generally less than the distance between structural columns in most buildings). Only 9 stairs are located further than 25 feet on average away from the MIP (Figure A.6). Due to the lack of variability in this data set, this variable will not be included in the bivariate regression analysis.

Two alternative variables were identified to measure the distribution of people in relation to the location of stairs within the building. One of the variables was the percentage of the total building occupant load served by each stair (Figure A.7). This variable reflects the distribution of the building's population in respect to the location of sedentary activities (seating spaces) within the building. The data sample indicates wide variability within the this variable's values ranging from a minimum of 3.2% for Stair GTCOAC (the building with the largest building area and number of vertical circulation options (6 stairs & 1 elevator)) to a maximum of 77.6% of the its building's total occupant load for Stair RYGCMA, (the building with the smallest building area and least number of vertical circulation options (2 stairs & 1 elevator). The alternative variable for distribution was the percentage of total building area served by each stair (Figure A.8). There was also wide variability in the values for this variable.

The variable, physical accessibility is an ordinal variable that describes the degree of ease of entry into the stair from the exterior of the building (1 = no entry, 2 = restricted entry, 3 = public access). Only three stairs (RYGCMB, RYENGC and RYENGD) provided no means of entry into the building from outside the building. These stairs were designed as exits only and provided no door hardware on the exterior face of the exit doors to facilitate entrance. While most doors (21 of 38) in the study were freely accessible to all building users, 34% of the stair doors had restricted hardware requiring keys or security cards to provide access.

6.2.2.2 Legibility Variables

This section examines the variance within the operationalized variables of the constructs of legibility: visibility, imageability and intelligibility of stairs.

The visibility of stairs were operationalized by two variables, the area of stair isovist which measured the average horizontal area of the visual field of each stair (Figure A.10) and the Area of interior vertical exposure (Figure A.11), which measured the visually transparent vertical area of an enclosed stairwell or open stair at the ground floor level. Measurements of both variables indicated that most stairs are not highly visible elements within buildings. Approximately half of all stairs in the study had both an average area of stair isovist per floor or interior vertical exposure of less than 500 square feet (about the same area as two and a half automobile parking spaces). Eighteen of the stairs had a greater range of visual exposure across the horizontal field of vision within areas of the building (stair isovist) suggesting that there was sufficient variance within the data set to explore the relationship between this variable and stair use. There was however, very little overall variance within the data set for the area of interior vertical exposure (Figure A.11). This indicates that stairs in buildings generally are either highly visible (grand stairs) or enclosed within are visually separated within fire-rated compartments (other stairs). Most of the fire stairs in this study had a small window of safety glass located within the door panel, mostly commonly 100 square inches or less in area. This glazing is provided to assess the safety of conditions on the immediate alternate side of the door (smoke, flame, and other persons). The low variance in the area of vertical interior exposure resulted in the elimination of this variable for statistical and graphic analysis in this study.

Stair Imageability is a variable that addresses the visual distinctiveness of stairs in buildings. It is an ordinal measure that distinguishes stairs as being either a grand stair or non-grand stair Grand stairs are generally distinctive in their form, materials and placement such that they convey by their appearance their presence and purpose as a means of vertical circulation. In this data set, each building has one grand stair except Building RYGCM which does not have a stair that fits the definition of a grand stair (Figure A.12). In this case the stair is similar in appearance to the other non-grand stair (RYGCMB) in the building. The major difference in form, appearance and materials is the larger width of the stair and additional width of stair entry door (double door).

Two variables that operationalize the intelligibility of a stair's location within their building were examined by measuring the complexity in terms of number of turns from the stair to two points of reference within the building. The number of turns between the stair and the closest entrance (Figure A.13) indicated that 40% of stairs are located within a single change of angular direction from their point of entry. Although 43 % of the stairs were located 2 turns from the building's entrance, six of the stairs had more angular complex routes through the building. The stair with the highest number of turns (RYENGD – 6 turns) did not have access to the interior of the building and the number of turns was measured between the ground floor entrance doors and the stair door on the second floor. The variability in the number of turns between the stair and the MIP is smaller (between 0.33 and 2.33 (Figure A.14)) than between the entrance and stair. It is noted that nearly all of the most integrated paths correspond to the public corridors of the buildings, where stairs are generally located.

6.2.2.3 Appeal Variables

This section examines, within the data set, the variance within the operationalized variables of the constructs of appeal: stair articulation, and setting appeal.

Stair Appeal was operationalized by an index created for this study, which classifies the degree of articulation of the stair form and finish. The distribution histogram of stair articulation (Figure A.16) indicates a well-distributed range of stair forms and finishes within the data set. Variability within the articulation of stairs within academic buildings was somewhat expected due to the nature of the academic building type, which is generally designed to satisfy unique requirements and expectations of academic programs. Academic buildings which must compile with institutions standards of design and construction are more likely to have higher standards of architectural design and finishes than most commercial workplace buildings built and operated for profit from tenancies. Although most grand stairs were classified within the most highly articulation class (Stair Appeal = 3), half of the non-grand stairs in these buildings were evaluated as having additional aesthetic attributes in some effort to improve their appeal. This suggests that the designers of these buildings have made an effort to present stairs to building users as an option for travel. This presents another way that the academic buildings of this study differ from many developer-built buildings that may accommodate many public workplaces. Most developer-built office buildings of more than 4 stories utilize poured in place concrete or unit masonry construction to create a service core to house the buildings elevators, stairs and service shafts. This service core provides lateral bracing to the structural steel frame of the construction of the rentable office space in the building. This building type has typically emphasized the use of the elevator for vertical circulation, often reducing the stairs to emergency exits. It appears that institutional low-rise buildings such as the buildings of the data sample provide as range of examples for future study on how the articulation of stairs may influence stair use.

Setting Appeal was operationalized in this study using an index created for this study which measures the quality of the view from the stair. Both campuses are located within large metropolitan urban centers, although the campus of Georgia Tech is significantly more open and landscaped than the dense urban campus of Ryerson University. The descriptive statistics illustrated in Figure A.15 indicates variability amongst the assessed values of the view settings from stairs. Ten of the thirty-eight stairs had no view to the outside their stair enclosure, while thirteen had views of landscaped areas and activity spaces such as lobbies and atriums that could provide sensory appeal while within the stair environment.

6.2.2.4 Comfort Variables

This section examines, within the data set, the variability within the operationalized variables of the constructs of comfort: gait compatibility, social operational compatibility and exertion compatibility.

Three variables were considered to operationalize gait compatibility in this study: riser height, tread depth, and the riser/tread ratio. Building regulations prescribe limits on the range of many of the study's variables. Several code standards have had authority over the design and construction of the buildings in this study due the range of age of buildings, differences in regulatory authority and due to the location of the two campuses. The Ontario Building Code (MMAH, 1997) regulates dimensional limits for riser height to be between 4 7/8 inches to 7 7/8 inches, and to be between 10 to 14 inches for stair treads (MMAH, 1997) for the buildings on the Ryerson University campus. BOCA regulations, which govern the construction of buildings on the Georgia Tech campus, are more restrictive. This code limits the range of the riser height from 4 to 7-7/8 inches and requires a minimum stair tread of 11 inches (no maximum is stated). The ratio of riser to tread is not prescribed by either building regulations having jurisdiction although architects generally utilize slopes recommended in graphic reference standards (Ballast, 1988; Ramsey, 1994; Liebing, 1999). Due the range in building age in this data set, the range of riser height and tread depth is larger than those allowed by current code requirements. This resulted in slightly higher riser heights in Stair RYINTB (8 inches) and narrower treads in stairs of Building RYARSC (8 and 9 inches) than current code requirements. Building regulations have provisions for the renovation of existing building (RYINT building was originally built circa 1920) which were regulated by codes that permitted narrower treads.

An examination of the distribution of riser height, tread depth and the riser/tread ratios indicate significant differences in their variability. The distribution of riser height illustrated in Figure A.17 in this data sample indicates that 23 of the 38 stairs (61%) have riser heights within a quarter inch of 7 inches. By comparison, there is a wider distribution of tread dimensions (Figure A.18) in the sample although 18 of 38 stairs have tread (50%) have tread depths within a quarter inch of 12 inches. Design practices for many firms likely establish 7 inches as the standard stair riser height when establishing floor to floor heights in buildings and once established all stairs within a building will have the same riser height when floor to floor heights across a single floor level is constant. There is a wider variability in tread depth as illustrated in Figure A.18. Tread depths tend to be the same for stairs with forms that are repeated within their building such as the non-grand stairs of buildings GTEL, GTIBB, GTMARC, RYARSC and GTUAW. However there was little similarity in tread depths within buildings that had non-standardized stair forms such as exists in Buildings GTCOA, RYENG and RYINT. In addition there was no clear pattern within the difference in tread depth between grand stairs and non-grand stairs in this data set. Amongst all the variables of gait compatibility measured in this study, the riser/tread ratio demonstrated the widest variability in values (Figure A.19), ranging from relatively shallow slope of .45 for the exterior stair GTCOAB (riser height 6, tread depth 13.25) to the steepest stair RYINTB (riser height 8", tread depth 9"). This study will examine the relationship between stair use and both tread depth and the riser/tread ratio, eliminating riser height from the remainder of the study due to low variability.

In this study, the number of risers between any landings operationalized the degree that a stair addresses the exertion compatibility of building users. Building regulations place limits of the maximum height of a stair flight between landings at 12'-0" (BOCA, 1999) or 12'-2" (MMAH, 1997). All the buildings except RYARSC (11'-6" floor to floor height) have floor to floor heights that require the provision of at least one mid-landing. Although floor heights in these buildings range from 11'-6" to 17'-6", most stairs in this group (25 of 33) have only one landing with a maximum 12 or 13 risers between landings (Figure A. 21). Only 5 stairs in 3 buildings in this study had more than one mid-landing. Three stairs, GTMARCA, RYARSCB and RYARSCC have only 5 or 6 risers per landings due to their tight spiral form. RYINTB has three landings between floors to minimize the floor area of the stair and its spatial impact of these stairs on the operational floor area of the building.

It should also be noted that the building's population tend to be more youthful and active than the general workplace population, the relationship between fatigue and stair use may not be evident in this study. Data collection was not conducted past 5 pm or during periods of final examinations and deadlines for end of term project work when this population would likely experience physical fatigue. Due to the limited variability within the number of risers between landings in this data set and the low expectation of fatigue amongst the building populations, this variable will not be included in further discussion on stair use in this study.

Social operational compatibility, a term that addresses the ability of group of people to engage in social conversation while traveling on stairs with comfort is operationalized by stair width. Building codes regulate the minimum size of stairs for emergency exiting purposes based on the occupant load of each floor level and the number of stairs serving each floor. In addition, building codes require a minimum overall stair width of 44 inches (BOCA, 1999) for the Georgia Tech buildings or 43 inches (MMAH, 1997) for the Ryerson University. All but one stair complied with these dimension (Stair RYMONB), which utilized the provision in the Ontario Building Code allowing alternative measures to code requirements for renovated buildings. In this case the narrower stair is allowed due to the low occupant load of the building and small floor area, which provides shorter than the maximum required travel distance between alternative exit stairs. Figure A.20 illustrates that stair width in this data set ranges from 36.75 (RYMONB) to 94.75 inches (GTCOAE).

6.2.2.5 Safety Variables

This section examines, within the data set, the variance within the operationalized variables of the constructs of safety: maintenance and natural surveillance.

The maintenance level variable is operationalized by an index created for this study. Figure A.22 indicates that no stair in the data set was determined to be inoperable due to poor maintenance, and with a mean of 7.55, the data set reflected a high operational standard of maintenance expected from this type of institutional building ownership. However five stairs, (GTCOAF, RYMONB, and all three stairs in Building RYARSC) scored within the 3 to 4 range of the index. All these stairs except RYARSCA are enclosed stairs that displayed evidence of poor maintenance due to wear and tear, cleanliness and intentional damage. Grand stair RYARSCA had a relatively poor maintenance score of 4 but was the best maintained stair within its building. Many of the best performing stairs within the buildings scored marginally below other stairs in their same building principally due to lower scores due to the wear and tear of use.

Natural surveillance for safety is operationalized in this study by the minimum illumination in footcandles (ftc.) measured on the steps and landing areas as described in Chapter 5. Building codes set a minimum standard of 1 footcandles for illumination of paths of egress, including stairs (BOCA, 1999). Figure A.23 indicates that all stairs in this study conformed to this regulatory requirement. The mean minimum illumination of this data set of 19.1 ftc indicating that this is generally a well lit group of stairs (range between 2 to 70 ftc.). The stairs with the lowest illumination (2 ftc.) include Stairs RYINTB, GTELD and GTELE. These lighting levels within these stairs, which made the stairwell appear dark, were still adequately lit to distinguish all surfaces and features within the stair environment.

6.3 Summary of Variability

This study examines the relationship between stair use and physical environmental variables with ten academic buildings on two university campuses that contain academic spaces including classrooms, laboratories, studios, libraries, workshops and offices, typically located along public corridors. The examination of variability in the values of both the dependent variable of this study, stair use, and the most of the independent variables displayed adequate variability to support the comprehensive range of hypothesis-testing that is the main focus of this chapter.

An important outcome of this analysis is that stair use occurs in workplace buildings across a full spectrum of frequencies ranging from almost unused staircase having less than half a percent of vertical circulation travel to staircases that provide the main role in the vertical circulation of people in the building.

The variability in values for stair use and the independent variable addresses several issues of validity within this study. One concern was the possibility that institutional standards would result in general uniformity in the architectural design of these buildings and their stairs. While there is some uniformity within the appearance or aspects of the placement of stairs in some buildings such as the non-grand stairs of Buildings GTIBB, RYARSC and GTMARC, most buildings had wider variability in the attributes and location of stairs due to layout of their functional spaces or building form and configuration. The buildings, which did possess some symmetry or modular characteristics in their form and placement of stair, rarely possessed similar symmetry and uniformity in the arrangement of the functional spaces or locations of main points of building entry and other site variables that affected views, accessibility, and location of the MIP. Even the introductory assumption of the stratification of stair use based on the two basic stair types (grand and non-grand) can be questioned due to wide variability in stair articulation within the buildings.

There was however there was insufficient variability within the sample for four variables. . These variables include the Distance between the Stair and the Most Integrated Path (MIP), Stair Openness Area, Riser Height, Maximum Number of Steps between Landings. Their absence from the subsequent analysis and discussion should not be construed as the elimination of their possible influence on stair design but as a limitation of the study's ability to fulfill sufficient variability for analysis of all the theoretical variables in a set of ten buildings.

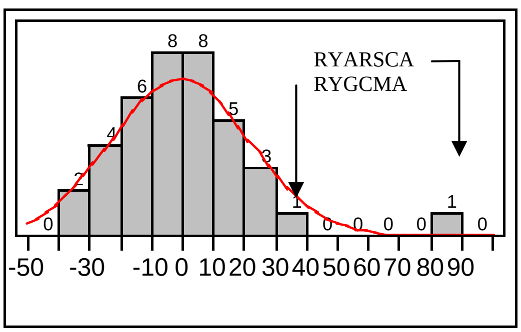
6.4 Analysis of Stair Use and the Variables of the Physical Environment

Statistical analysis provides a means in which to investigate the strength of relationships between sets of the variables. This study will test the set of hypotheses presented in Chapter 5, by utilizing bivariate linear regression to examine the relationship between the measured value for stair use and the measured values for each individual operationalized variable. It was determined that bivariate linear regression is the most appropriate means for testing the research hypotheses for a relatively small sample size of 38 stairs.

As linear regression assumes several basic assumptions, this study examined the data in respect to the four basic assumptions of this method to acknowledge its usefulness and limitations. One assumption of linear regression is that the data sets are independent. Data sets, such as values for stair use and their physical environmental attributes with the ten buildings of this study are inherently clustered and would normally be analyzed using multi-level or hierarchical regression methods. In hierarchical models, it is assumed that individual level parameters such as those of the individual stairs are influenced by attributes of the individual buildings in which they are clustered at different levels. Using this study to illustrate, data is nested at three levels: stair level, building level and campus level. One major requirement of multilevel modeling is a fairly large sample size within each cluster, which frustrates the use of a hierarchical method for this study. The sample size at each level of this study data is small; there are between 2 to 6 stairs located in each of the 10 buildings on the 2 university campuses. To address this issue, the data sets were analyzed to ensure that no campus and building level variables influenced the patterns of stair use within the data.

Another assumption of linear regression is that the true relationship between variables is linear. This assumption was tested by examining the scatterplots produced for each bivariate analysis. Scatterplots for those variables that indicated a significant relationship with stair use are provided in the Appendix A, Figures A.25 to A.34). Although none of the scatterplots displayed perfect linearity, and some minor heteroscedasticity and several outliers were evident within the scatterplots, there is a general linear pattern evident in each of the graphs. Only the variable, *distance from the stair to the MIP* deviated from a linear pattern. The scatterplot of this variable suggests that there is no relationship between stair use and the distance from the MIP within a distance of 25 feet, although beyond that threshold a negatively-sloped linear relationship may exist. As there were only eight stairs located further than 25 feet from the MIP, this variable was not included in further analysis.

Another assumption of linear regression is that the values used have a normal distribution around the mean =0. The previous section confirmed the robustness in the variability of measures for stair use and sixteen physical environmental variables for hypothesis-testing. The data values for each of these variables were modified to approximate a normal distribution, satisfying one of the basic assumptions for regression by a z-score method outlined in Appendix A (Kohout, 1974). The normal distribution of data for both stair level and building level variables are illustrated in Figure 6.4 and 6.5 respectively. The final basic assumption of linear regression is that the variance in the error component is the same for each variable. Linear regression is commonly utilized when examining complex decision making in real life issues such as the influences of stair use even when the variance of the error term is not constant or present a tightly linear profile in bivariate analysis. A visual examination of residuals of these plots appears random, thus reducing concern over this issue.



Mean	0.00
Std Dev	22.39
Minimum	88.93
Maximum	-37.63
N	38

Normal Distribution

Figure 6.3 Distribution of Normalizing Individual Stair's Use as a Percent of Vertical Circulation in their Building

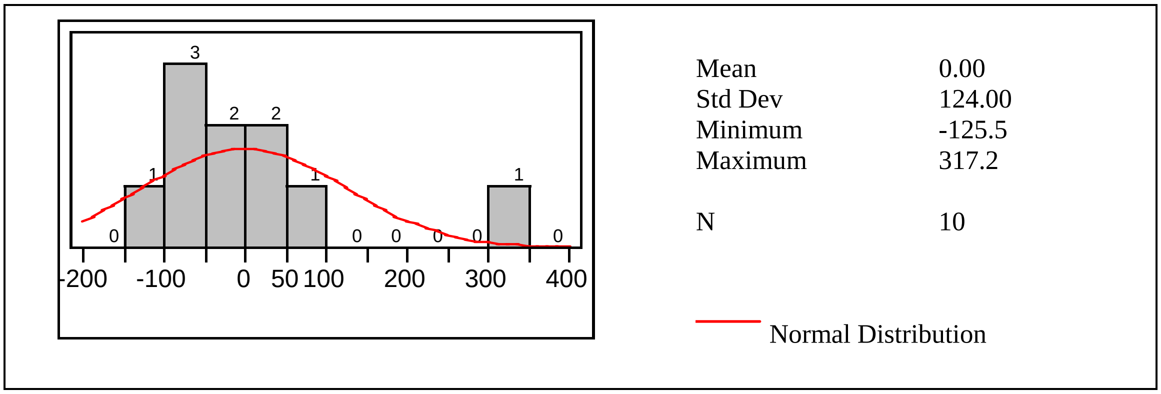


Figure 6.4 Distribution of Normalized Overall Building Stair Use as a Percent of Vertical Circulation in their Building

The nesting of the stair data within buildings appears to be the most contentious issue in respect to the independence of the data and use of bivariate linear regression for testing the hypotheses. The study addressed this issue by examining campus and building level variables to determine that there was no between stair use and key aspects of building design or location in this data set. It would be advised in further research to substantially increase the size of the data sample, to provide for data set with sufficient data at each level for the use of multilevel regression methods

6.4.1 Campus and Building Level Variables

Nine potential building level variables, which addressed three basic aspects that may influence stair use, were examined in this study. One of these aspects, building location, was examined to determine if stair use was associated with location of the campus (Atlanta vs. Toronto). The second set of variables addresses the issue whether the relative size of a building may influence stair use patterns. The third set of variables addresses the influence of several building level attributes of the building’s elevators on stair use. Table 6.2 presents an analysis of the bivariate relationship between the selected building level variables and stair use. A bivariate regression analysis of the building level variables and building stair use indicated no significant effects at the building variable level could be distinguished.

Table 6.2 Analysis of Campus Level and Building Level Variables and the Percentage of Stair Use in their Building

Building Level Variables	Adjusted R^2	F ratio	Significance Prob>(t)
Campus Level Variables			
Campus Location	-22e-16	-	-
Building Level Variables			
Number of Stairs in Building	-0.03281	0.714	0.4227
Number of Floors	-0.30	0.741	0.414
Total Building Area	-0.08	0.332	0.580
Floor Level Area	-0.002	0.980	0.351
History of Elevator Interruption	0.00	-	-
Elevator Speed	0.053	1.50	0.256
Elevator Capacity	0.103	2.04	0.191
Number of Elevators	0.016	1.15	0.315

6.4.2 Stair Level Variables – Testing the Hypotheses

This study used a series of bivariate regressions to examine the statistical relationship between stair use and specific physical environmental variables within 3 or 4 story academic buildings. Based on the developing discussion within the last several chapters, the research hypotheses have been refined and will be testing using bivariate regression to examine the goodness of fit between stair use and the 16 variables that operationalize the refined thematic framework illustrated in Figure 5.1. The research hypotheses presented as follows:

- Stair use is related to the relative position and accessibility of stairs with other spaces within buildings which support the **Convenience** of stairs for purposeful multi-level travel, defined by the proximity of stairs to key places of travel orientation, the distribution of the building population, and physical accessibility. This hypothesis will be addressed by examining the following series of null hypotheses:

H_{01}: The distance between stairs and the nearest entrance is unrelated to stair use.

H_{02}: The distance, between stairs and the elevator is unrelated to stair use.

H_{03}: The relative distribution of persons measured by calculating the occupant load of a building within closest metric proximity of a stair is unrelated to stair use.

H_{04}: The relative distribution of stairs within a building's floor area in respect to measuring the floor area, which is closer to one stair than any other, is unrelated to stair use.

H_{05}: The relative physical accessibility between the stairs and exterior or interior spaces within the building is unrelated to stair use.

- Stair use is influenced by the relative visibility, imageability or intelligibility of stairs within buildings that facilitate the **Legibility** of stairs for purposeful multi-level travel. This hypothesis will be addressed by examining the following series of null hypotheses:

H_{06}: The visibility of stairs measured by the average area of stair isovist is unrelated to stair use.

H_{07}: The provision of a highly imageable stairs identifiable as a grand stair is unrelated to stair use.

H_{08}: The number of turns from the stair to the closest entrance is unrelated to stair use.

H_{09}: The number of turns from the stair to the most integrated path is unrelated to stair use.

- Stair use is influenced by the relative appeal of a stair as a object, or the setting in which a stair is located within buildings that operationalize the **Appeal** of stairs for purposeful multi-level travel

  H_{10}: The articulation of a stair is unrelated to stair use.

  H_{11}: The setting of the view from a stair is unrelated to stair use.

- Stair use is influenced by features of the stair environment, which are compatible with the gait, exertion, or operational situation of the user that operationalize the **Comfort** within the stair environment.

  H_{12}: The depth of the tread surface is unrelated to stair use.

  H_{13}: The ratio of the riser height to tread depth is unrelated to stair use.

  H_{14}: The metric width of a stair is unrelated to stair use.

- Stair use is influenced by features of the stair environment, which support and prevent injury or apprehension during use, that operationalize the **Safety** of stairs.

  H_{15}: The maintenance level of stairs is unrelated to stair use.

  H_{16}: The minimum illumination within the stair environment is unrelated to stair use.

The results of the bivariate regression analysis used to test the above hypotheses are provided in Table 6.3. The results, when considered as a whole, indicate the importance of the conceptual themes of convenience and legibility in relation to general stair use in the buildings and are consistent with the high level of importance placed on these factors by survey participants of the survey of reasons for route choice conducted in Chapter 4.

Table 6.3 Results of the Bivariate Analysis of the Relationship between Stair Use and Physical Environmental Variables

	Adjusted R^2	F ratio
Physical Environmental Variables		
Convenience		
Proximity		
Travel Distance between Stair & Nearest Entrance	0.088 *	4.57
Travel Distance between Stair & Elevator	0.153 **	7.68
Distribution		
% of Total Building Occupant Load	0.276 ***	15.10
% of Total Building Area	0.247 ***	13.14
Accessibility		
Physical Accessibility	0.127 *	6.39
Legibility		
Visibility		
Average Area of Stair Isovist	0.310 ***	17.60
Imageability		
Stair Type	0.317 ***	18.21
Intelligibility		
Number of Turns from Closest Entrance	0.164 **	8.28
Number of Turns from Most Integrated Path	0.174 **	8.79
Appeal		
Setting Appeal		
Views	0.013	1.47
Stair Appeal		
Stair Articulation	0.057	3.22
Comfort		
Gait Compatibility		
Tread Depth	0.018	1.69
Tread Riser Ratio	-0.002	0.93
Exertion Compatibility		
No variable considered in this study		
Social Operational Compatibility		
Stair Width	0.148 **	7.43
Safety		
Maintenance		
Maintenance Level	-0.020	0.26
Natural Surveillance		
Minimum Illumination (ftc)	-0.024	0.13

******* (significant at .001); ****** (significant at .01); ***** (significant at 0.05)

The results of the bivariate analysis indicate that we are able to reject the null hypotheses for all the variables of convenience and legibility at a significance level of at least 0.05.

The analysis indicated a relationship between all five variables that operationalized convenience in this study. In the case of the proximity variables, Distance *between Stairs and the Closest Entrance* (Adjusted R^2 = 0.088, prob. <0.034) or *Distance between Stairs and the Elevator* (Adjusted R^2 = 0.153, prob. <0.009); the relationship with stair use decreases as the travel distance increases. The regression analysis produced very similar values for both alternative measures of distribution variables: the *Percentage of Total Building Occupant Load* (Adjusted R^2 = 0.276, prob. <0.0004) and the *Percentage of Total Building Area* (Adjusted R^2 = 247. prob. <0.0009). The analysis also indicated a relationship between stair use and *Physical Accessibility* between stairs and other spaces of the buildings (Adjusted R^2=0.127, prob. <0.016)

The analysis also indicated a relationship between all four variables that operationalized legibility in this study. In the case of the visibility, *Average Area of Stair Isovist* (Adjusted R^2 = 0.310., prob. <0.0002), stair use increases with the extent of the floor area that a stir is visible. The imageability variable, Stair *Type* (Adjusted R^2 =0.317, prob. <0.001), confirmed that grand stairs are associated with higher frequencies of use than non-grand stairs. The regression analysis also indicated a relationship between stair use and both variables of intelligibility, Number *of Turns from the Entrance to the Stair* (Adjusted R^2 =0.164, prob. < <0.0067) and the *Number of Turns from Stair to Most Integrated Path* (Adjusted R^2 =0.174, prob. < <0.0053). This supports the inference that increases of angular complexity (axial depth) between the stair and either the building entrance or most integrated paths reduces stair use.

These findings reveal the importance of close spatial relationships between stairs and key paths and nodes of a building's circulation system such as the building entrance, elevator and most integrated paths of travel when considering how to optimize stair use within buildings.

It was not possible to reject the null hypotheses that address the appeal and safety of stairs within this data sample. In addition, it was also not possible to reject the hypothesis that stair use is unrelated to the comfort aspects of gait compatibility. Although a previous stair use research study indicated that upgrading the aesthetic finishes of stair environments can increase stair use among building users (Kerr, Yore et al. 2004), this study, which focused on stair use within a broader sample and range of stair environments, did not provide statistically significant evidence that the local features of stairs that largely comprise the appeal, comfort and safety variables of stairs have an effect on occupants familiar with the building. This does not suggest that human response to these variables does not affect stair use but it may instead reflect that these issues may have only occasional rather than widespread importance for route choice decisions during purposeful travel. It is also possible that there is little importance given to issues of comfort, appeal and safety among the young, agile and busy population of these relatively attractive and well maintained buildings. While a future study with an older and more sedentary population may provide greater insight into these variables, it is apparent that healthy populations place greater importance on the features of stairs and buildings that facilitate the convenience and legibility of purposeful travel over other factors.

Amongst the variables of comfort, safety and appeal, only stair width, which operationalized comfort by the social operational compatibility of stairs, indicated a statistically significant relationship with stair use in this sample. When considered in the context of the interest and priorities of travel within this youthful population, this variable likely reflects the social aspect of the academic environment in which building occupants may walk together in small social groups around structured class schedules.

An important finding of this statistical analysis is that stair use is principally associated with the spatial characteristics of stairs that define their location and visibility in relation to key elements of the building:1) building entrance, 2) building elevator, 3) the most integrated paths of the building, and 4) the distribution of people and/or floor area. Stair width was the only spatial variable associated with stair use that defined a local attribute of the stair environment. The only non-spatial variable associated with stair use in this study was Stair Type (grand or non-grand), which operationalized the imageability of a stair designed to general travel. It has been an initial assertion in the dissertation that architects provide grand stairs to signify stairs designed for primary vertical travel by stair. However, it now appears questionable whether grand stairs attract stair use based on their appointment or on their spatial characteristics. There is no doubt that stairs defined as grand stairs, have both imageable and spatial characteristics that may influence stair use.

However, a simple addition of the R^2 value of the variables associated with stair use suggests there may be some colinearity between the spatial variables. While some of this colinearity may be embodied within the attributes of a grand stair, the spatial attributes of stairs, not the expressive appoint of stairs, warrants greater study. Thus, this study will focus on the key spatial variables of stair use identified in the bivariate regression analysis.

6.5 The Key Spatial Measures associated with Stair Use

6.5.1 An Analysis of Collinearity

The regression analysis indicated a significant relationship between stair use and five measures of convenience, four measures of legibility and one measure of comfort. Although the themes of Convenience, Legibility and Comfort had been divided into the more refined constructs (Convenience: proximity, distribution and accessibility: Legibility: visibility, imageability and intelligibility, and Comfort: social operational compatibility) in order to define, identify and theoretically reduce the likelihood of colinearity between the variables, this study had not analyzed the possible correlations between these measures. A colinearity analysis of the ten variables was undertaken using statistical software, which produced a scatterplot and density ellipse (0.90) of each relationship. This allowed for a visual analysis of graph and numerical value of correlation between the variables. The colinearity analysis indicated two issues related to colinearity in the study.

The first issue, evident in the colinearity analysis illustrated in Table 6.4, was the high colinearity between several of the variables considered in the study. There is notable correlation of 0.894 between the distribution variables: the *Percentage of Total Building Area* and the *Percentage of the Total Occupant Load* which were suggested as alternative measures of the distribution of the stairs within the building. Within this data sample, it appears that the occupant load is generally well distributed over the building area and that both variables appear similarly associated with stair use patterns within a building. In the multivariate analysis, it is necessary to input only one of the variables into the regression equation. *Percentage of Total Building* Area will be used to as the variable for distribution.

The analysis also indicated a high correlation of 0.750 between the variables: *Average Area of Stair Isovist* and *Stair Type*. In addition, analysis indicates a degree of correlation between stair type and several other variables of convenience: the *Distance between the Stair and Elevator* (0.395), *Distance between the Stair and Entrance, Physical Accessibility* (0.257); and both the alternative variables operationalizing distribution: the *Percentage of Total Building Area* (0.354) and *Percentage of the Total Occupant Load* (0.407). One of the basic assertions of the introductory chapter was that stratification of stairs within buildings reflected the higher stair use amongst grand stairs has been illustrated in Figure 6.2. While this study provided evidence that supported this assertion, it also reveals the imageability of a stair may be inseparable from other attributes of grand stairs such as the extent of its visibility.

The second issue of colinearity evident in the analysis was the general lower levels of correlation indicated between many of the variables. Colinearity values between .25 and .5 between variables indicate that the variables are not fully independent as they are nested

Table 6.4 Colinearity Analysis of the Key Variables of Convenience, Legibility and Comfort

	Convenience					Legibility				
	Travel Distance from Stair to Entrance	Travel Distance from Stair to Elevator	Travel Distance from Stair to MIP	% Total Building Area	% Total Building Occupant Load	Physical Access.	Average Stair Isovist	Stair Type	Number of Turns from Stair to Entrance	Number of Turns from Stair to MIP
Travel Distance from Stair to Entrance	*	.218	.08	-0.046	-0.102	-0.445	-0.244	-0.253	0.547	0.401
Travel Distance from Stair to Elevator		*	.385	-0.395	-0.366	-0.246	-0.350	-0.395	0.244	0.236
Travel Distance from Stair to MIP			*	-0.096	-0.134	-0.026	-0.155	-0.214	0.203	0.501
% Total Building Area				*	0.894	-0.411	0.149	0.354	-0.188	-0.203
% Total Building Occupant Load					*	0.1224	0.227	0.407	-0.238	-0.251
Physical Accessibility						*	0.389	0.257	-.5277	-0.272
Average Stair Isovist							*	0.750	-0.362	-0.247
Stair Type								*	-0.249	-0.231
Number of Turns from Stair to Entrance									*	-0.380
Number of Turns from Stair to MIP										*
Stair Width	-0.1259	-0.338	-0.143	0.071	0.105	0.397	0.342	0.184	-0.223	-0.246

within the arrangement of key points of reference (location of stairs, entrances, elevators and MIP), and attributes (accessibility and visibility) that comprise the circulation system of buildings and result in the key issue of choice between stair or elevator. The spatial nature and the co-relationship amongst the variables of the study will be explored within the graphic analysis of the key variables in the next chapter.

6.5.2 A Spatial Model for Stair Use - Multivariate Analysis of Stair Use and the Variables of the Physical Environment

Through an empirical study of ten buildings-in-use, this study has considered a large number of possible variables that may be associated with natural patterns of stair use within public workplace buildings. The study has refined this large number of possible variables to identify spatial variables for further statistical analysis in order to develop a spatial model that explains stair use in these buildings. Multiple regression methods provide a statistical technique for developing such models by examining the relationship between a dependent variable and several other independent variables.

In a multiple regression analysis

$y = b_0 + b_1 (x_1) + b_2 (x_2) + e$

Where y = dependent variable = Stair Use

b_0 = intercept term

b_1= parameter estimates

x = independent variables

e = residual

Based on the principle hypotheses of this study, the multiple regression equation could be conceptually described as:

Stair use = b_0 + b_1 (Convenience) + b_2 (Legibility) + b_3 (Appeal)

+ b_4 (Comfort) + (b5 (Safety) + *e*

Based on the variability, bivariate and collinearity analyses performed earlier in this chapter, the resulting conceptual equation for the analysis of a spatial model for stair use within the data set of the ten academic program buildings could be stated as follows:

Stair Use	=	b_0	(Intercept)
	+	b_1	(Travel Distance from nearest Entrance)
	+	b_2	(Travel Distance from between Stair & Elevator)
	+	b_3	(% of Total Building Area)
	+	b_4	(Physical Accessibility)
	+	b_5	(Area of Stair Isovist)
	+	b_6	(# of Turns from Entrance to Stair)
	+	b_7	(# of Turns from Most Integrated Path)
	+	b_8	(Stair Width)
	+	e	(Residuals)

This analysis utilized a stepwise regression method available in the statistical software which can automatically run a forward or backwards selection process which permits the computer to select and calculate the order in which variables are added to or subtracted from the equation until a model in which all variables are significant to a desired level (p is not greater than 0.10). In this analysis, all eight spatial variables of stair use were entered into the regression model and the software generated, through a series of steps, a model in which all variables are significant at $P < 0.05$. The software also allows for the selection of variables in order to view the effect of sequentially reducing the number of variables by their significance level in this model until only one variable remains. The results of these stepwise regressions are illustrated in Table 6.5.

Table 6.5 Summary of Stepwise Multivariate Regression Analysis of the Spatial Model for the Ten Academic Buildings

Stepwise Model	8	7	**6**	5	4	3	2	1
Adj. R^2	0.247	0.492	**0.531**	0.558	0.565	0.566	0.545	0.529
F Ratio	13.14	18.89	**15.01**	12.68	10.60	9.053	7.32	6.196
Model Prob>F	0.009	<0.001	**<0.001**	<0.001	<0.001	<0.001	<0.001	<0.001
Parameter Estimates								
Percent of Building Area	0.784***	0.667 ***	**0.601 ****	0.603 ***	0.633 ***	0.636 **	0.630 **	0.22 **
Average Stair Isovist		0.007 **	**0.006 *****	0.005 **	0.004 **	0.005 **	0.004 **	0.004 *
Average Turns from MIP			**-11.41 ***	-9.93	-8.74	-7.10 *	-7.128	-6.96
Stair Width				0.270	0.218	0.231	0.225	0.224
Physical Accessibility					5.044	3.965	3.904	3.761
Travel Distance from Entrance						-0.027	-0.026	-0.025
Avg. Travel Distance from Elevator							-0.007	-0.007
Turns from Entrance								-0.025

******* (significant at .001); ****** (significant at .01); ***** (significant at 0.05)

This analysis provided only one model in which all variables were significant at 0.05. This model identified three variables: the *Percent of the Total Building Area* served by each stair, the *Average Stair Isovist* and the *Number of Turns from the Most Integrated Path*, which explain 53.1% of stair use in the ten academic buildings. No other variable in the equation produced a significant result at p=<0.05 although several models with slightly higher adjusted R^2 values were generated.

The three variables of the model provide an interesting perspective on stair use in these buildings. At the most general level, it appears that stair use is most highly related to or its geographic location within the buildings (or alternatively) the distribution of people around the stair), such that the shorter distance one has to travel to a stair, the more likely that one will be it. Secondly, stair use is highly related to their visibility in a building, such that the more visible a stairs is across the floor area of the building, the more likely it will be used. Thirdly, it appears that stair use is related how complexity the journey to the stair is, such that increasing the number of turns required to navigate between the most integrated paths of the building will decrease the likelihood of a stair being used.

A review of the whole model leverage plot (Figure 6.6), residual plot (Figure 6.7) and effect leverage plot for each variable (Figure 6.8) for the 3-variable spatial model provides a means to visually assess the fit between the variable values and stair use. While the whole model leverage plot appears to suggest a strong model, the effect leverage plot for the average stair isovist suggests that the effect, although highly significant may be highly influenced by the values of three stairs (RYARSCA, GTIBBBA and GTMARCA) located in large lobby atriums within the data set. This in itself is not sufficient in the opinion of the author to disregard the effect but it exposes the major limitation of utilizing a statistical analysis with this relatively small sample of buildings and stairs. Certainly these statistical results need further analysis, either by focusing on a sample of stairs and buildings which

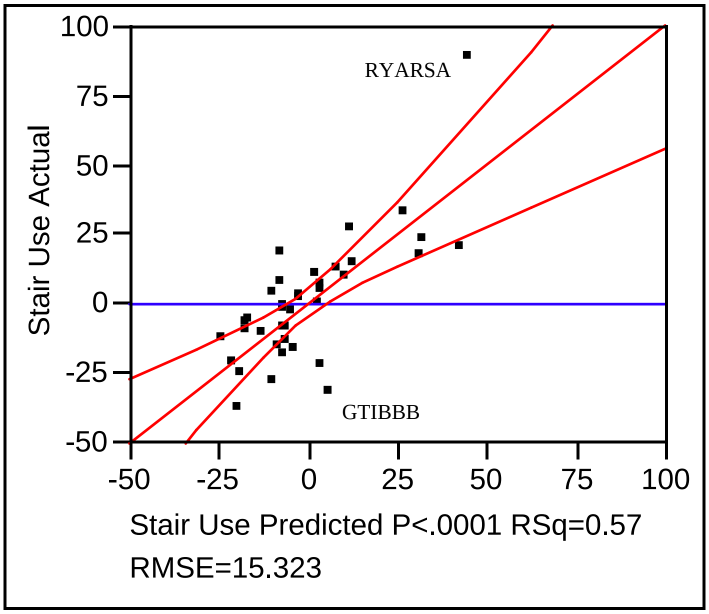
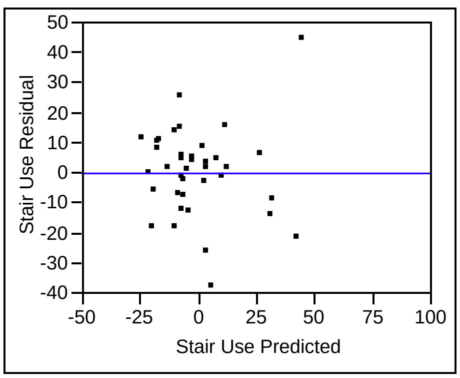


Figure 6.5 Whole Model Plot for Spatial Measures which explain 53.1% of Stair Use in the Ten Academic Buildings



RSquare		0.569725		
RSquare Adj		0.53176		
Root Mean Square Error		15.3232		
Mean of Response		-0.00042		
Observations (or Sum Wgts)		38		
Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-7.359555	10.40654	-0.71	0.4843
% of Building Area	0.6010501	0.174904	3.44	0.0016
Average Stair Isovist Area	0.0060146	0.001561	3.85	0.0005
Average Turns from MIP	-11.41079	5.707983	-2.00	0.0536

Figure 6.6 Spatial Model Residuals

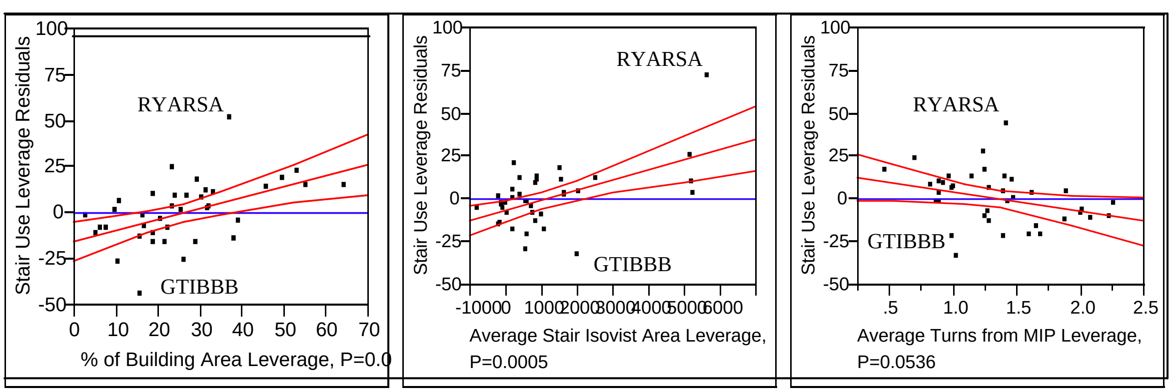


Figure 6.7 Spatial Model Leverage Plots

provide a greater variance in the values for the 3 variables of the spatial model and possibly the eight variables of convenience, legibility and comfort from which the multiple regression analysis began with.

6.6 Chapter Summary

This chapter presented a study that used statistical methods to address discussed four main outcomes. An

1) An examination of the variability within the selected physical environmental variables indicated that 17 of the 20 variables identified for hypothesis-testing had adequate variability for analysis. Three variables, riser height, interior vertical exposure and the travel distance from the stair to the MIP were determined to have insufficient variability for examination in this study.

2) Testing of the 17 hypotheses related to the constructs of Convenience, Legibility, Appeal, Comfort and Safety, identified ten physical environmental variables associated with stair use. With consideration of both the analysis and its limitations, this study established that there is a strong relationship between 9 key spatial measures and stair use:

- Travel distance from stair to nearest entrance
- Travel distance from stair to elevator
- Percentage of total building area
- Percentage of total occupant load
- Physical accessibility
- Average area of stair isovist

- Number of turns from closest entrance
- Number of turns from stair to most integrated path
- Stair width

3) An examination of colinearity amongst the 9 key spatial variables suggests the variables have some degree of correlations. The analysis suggests that this correlation may be the result of architectural practices that tend to group the characteristics associated with stir use into composite typologies such as grand stairs, or buildings with entrances and elevator s located within large atriums.

4) A multivariate regression analysis of the 9 key spatial variables identified three variables: the *Percent of the Total Building Area* served by each stair, the *Average Stair Isovist* and the *Number of Turns from the Most Integrated Path*, explained 53.1% of stair use in the ten academic buildings.

The study is this chapter has several limitations. One limitation is that the small sample limited the use of a more preferential statistical method for clustered data: hierarchical liner regression. Within the time and budgetary restrictions of this study, it was not possible to gather information of a sufficient sample (estimated at approximately 100 buildings or 350 stairs) to utilize this method for the number of variables under consideration. The analysis however did address within the limitations of the sample that no campus or building level attributes appeared relevant to stair use patterns in this data set. The bivariate method was therefore appropriate but not ideal. Another limitation comes with nature of cross-sectional studies. The colinearity amongst the variables may leave open to some concern for the spuriousness of some of the variables. It is important to reiterate that the study and its findings identify the variables associated with stair use, not the determinants of stair use. The casual issues of stair use warrant future study but can built on the measures and relationships identified in this study.

In Chapter 7, the final stage of the study will examine the spatial variables in each building of the data set graphically to understand how these variables interact within the layout of buildings to explain stair.

CHAPTER 7
GRAPHIC ANALYSIS OF THE KEY SPATIAL VARIABLES ASSOCIATED WITH STAIR USE IN THE TEN BUILDINGS

The previous chapter examined the statistical relationships between the physical environment variables and stair use in the 38 staircases in 10 buildings. This chapter explores each building as a case study of the arrangement of key spatial variables.

This chapter includes the graphic case studies of the following stairs:

7.1 Graphic Analysis of the Data Set as Case Studies

7.2 High Stair Use: Single Stair Strategy

- 7.2.1 Building RYGCM
- 7.2.2 Building RYARSC
- 7.2.3 Building GTMARC

7.3 High Stair Use: Multiple Stair Strategy

- 7.3.1 Building GTEL
- 7.3.2 Building RYINT
- 7.3.3 Building GTUAW
- 7.3.4 Building GTCOA

7.4 Lower Stair Use Buildings

- 7.4.1 Building GTIBB
- 7.4.2 Building RYENG
- 7.4.3 Building RYMON

7.5 Summary

7.1 Graphic Analysis of the Data Set as Case Studies

In this chapter, each building is examined individually as a case study of the relationships between stair and elevator use and the following key spatial variables of stair use identified in the bivariate regression analysis in Chapter 6:

- Travel distance from building entrance to the stair (in feet)
- Travel distance from the stair to the elevator (in feet)
- Percentage of total building area (effective area) served by the stair
- Percentage of total occupant load served by the stair
- Physical accessibility (the ease of moving from the staircase to other areas of the building)
- Average area of the stair isovist (the size of the building floorplate that can view the staircase
- Number of turns from the building entrance to the stair
- Number of turns from the MIP (most integrated path) to the stair
- Stair width

The case studies in this chapter have been arranged into the following three sets:

- High stair use (at least 60% of vertical trips are by stairs):
  - Single stair strategy: stair use is concentrated predominantly on one stair in the building
  - Multiple stairs strategy: stair use is distributed amongst several stairs within the building
- Lower stair use (less than 60% of vertical travel by stair)

Each building case study focuses on how the graphic representation of the key spatial variables on the building's floor plans explains stair use in each building. Detailed information on each stair is provided in the data sheets in Appendix B.

7.2 High Stair Use: Single Stair Strategy

Three buildings within the data set recorded high overall stair use predominantly due to the use of one stair in the building. These buildings range in their buildings size, complexity and the arrangement of their corridors and paths of travel, and the number of stairs (2 to 5) and building height (3 and 4 levels). Each building has only one elevator. The case studies indicate that when the arrangement of the key spatial variables augments the convenience and legibility of one stair over all other options for vertical travel, this may result in a building with high stair use.

7.2.1 Building RYGCM

Building RYGCM is notable because it has a high proportion of building users who take the stairs rather than elevator for vertical travel (stairs are used for 73.4% of vertical travel) and stair use is concentrated on a single stair. Stair RYGCMA is used for 65.6% of vertical travel. Elevator RGCMELV attracts 25.7% of vertical travel and Stair RYGCMB attracts a relatively low 8.7 %.)

The building, constructed in 2002, houses a department of graphic communication management, a program that educates professionals for the publishing industry. The building contains administrative offices, washrooms and a receiving bay on the first floor, a large

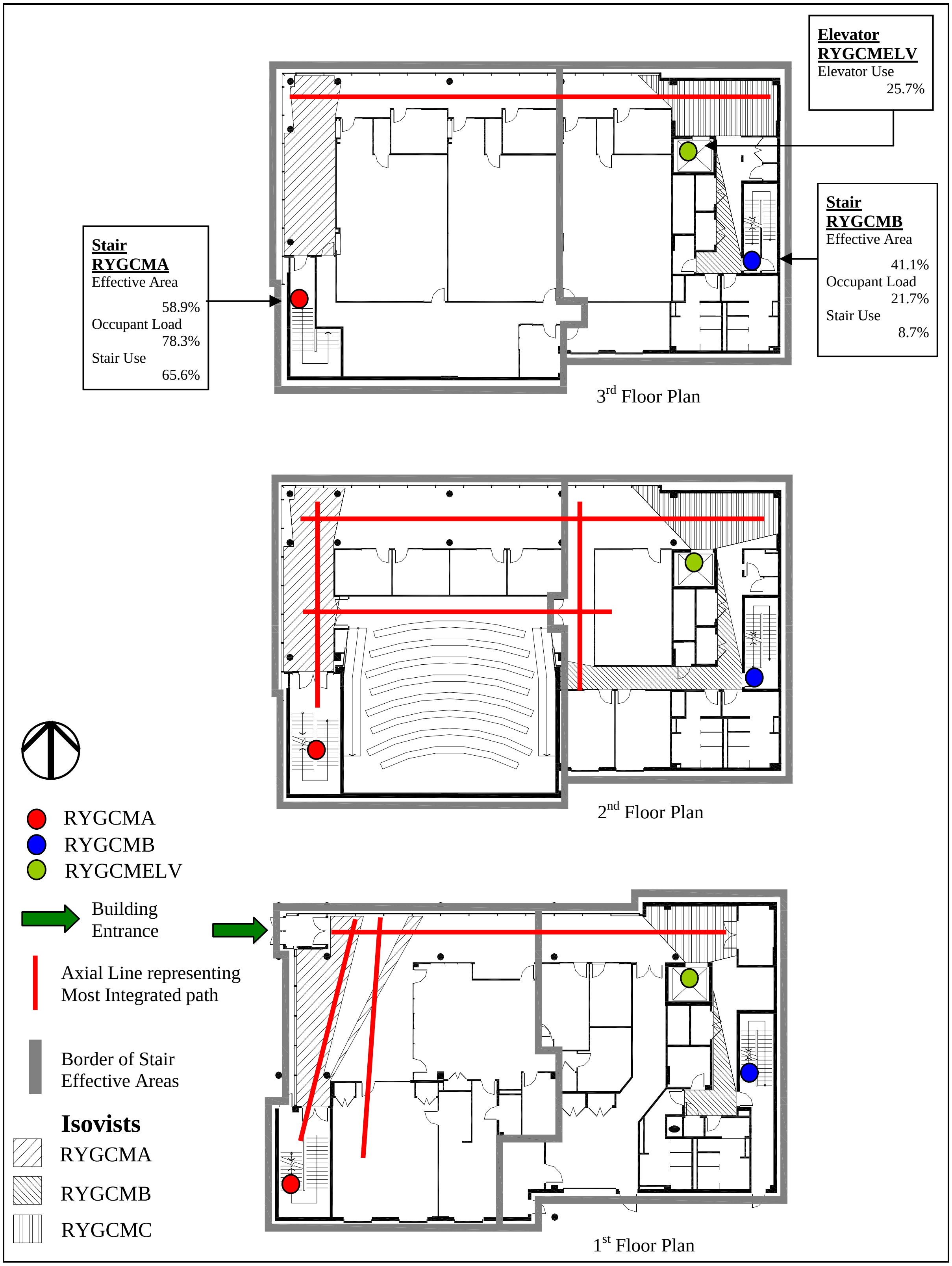


Figure 7.1 Building RYGCM
Graphic Representation of Key Spatial Variables of Convenience & Legibility

lecture hall and offices on the second floor and classrooms, computer labs and faculty offices on the third floor. Although there are four sets of exterior doors, three are locked fire exits and general users have access to only one entry. There is a spacious L-shaped lobby that organizes the functional spaces on each floor. Unlike all other buildings in the data set there is no grand stair. The two stairs in this building are located at the opposite ends of the building and are enclosed by fire-rated compartments separated from the circulation lobbies and corridors. Both stairs have similar simple steel pan construction and basic finishes including vinyl treads and risers, painted drywall walls and fluorescent lighting.

Stair RYGCMA, the best–used stair has the following characteristics compared to the elevator and the other stair in the building. It:

- Is closer to the entry in terms of walking distance (metrically closer);
- Requires fewer turns to reach the entry (has less syntactic depth from the entrance);
- Has a larger effective area (is nearer a greater proportion of the floorplate);
- Has a larger occupant load (is closer to more seating positions);
- Is directly visible from a larger area of the building (has a larger isovist area);
- Is visible from a larger area of the main hallway (has a larger isovist area on the most integrated path).
- Requires fewer turns to reach the MIP (has less syntactic depth from the most integrated paths)

Stair RYGCMA is the only option for vertical travel located near the one entrance to this building. Further, the isovists of the stairs and elevators in this building are exclusive;

such there is no one location within this building in which building users are faced with making a comparative visual choice between stairs and elevators. This lack of comparative perspective, especially from the main entrance, likely contributes to the use of Stair RYGCMA.

Figure 7.1 illustrates how both the alternative measures for the distributive variable; percentages of total effective area and total occupant load are independently relevant to stair and elevator use within the building. It is evident from the floor plans, that the densely populated spaces within this building such as the classrooms and the lecture hall are located within the effective area of Stair RYGCMA even though some of the classroom doors are metrically closer to the elevator than Stair RYGCMA. Such rooms tend to accommodate activities, such as lectures, where people may arrive in small numbers over a relatively short period of time, but leave the room as a concentrated group often within a much tighter time frame once their activity is completed. A highly concentrated population can perceive the stair as a more convenient option than the elevator, which has limited ability to accommodate large groups in a timely manner.

The elevator, which is located centrally within the effective area of Stair RYGCMB and with closer proximity and visibility to the MIP, appears to captures major portion of occupant load within the effective area of Stair RYGCMB, thus contributing to this stair’s limited use. The low use of Stair RYGCMB can be understood as a product of its visual, metric and syntactic remoteness from both the building’s entrance as well as the most integrated path of travel (MIP) within the building.

7.2.2 Building RYARSC

Building RYARSC is noteworthy because a high proportion (85.2%) of vertical travel with in the building is by stair use, concentrated primarily on a single stair. Stair RYARSCA is used for 77.6% of all vertical travel. There are two other stairs in the building, Stair RYARSCB, which attracts 5.0 % of vertical circulation and Stair RYARSCC, which attracts 2.5% of vertical circulation. This building also contains an elevator within the atrium immediately adjacent to the grand stair, which accounts for 14.8% of all vertical circulation.

Building RYARSC is a four-story building constructed in 1981, which houses a program for the study of architectural science. The ground floor contains the program's library, workshops, presentation gallery and large lecture hall. The majority of the second to third floor areas of the building is allocated for studio space but also contains faculty offices, computer and seminar rooms all organized on either side of a large central atrium.

Stair RYARSCA has the following characteristics compared to the elevator and the other stairs in the building. It:

- Is closer to the 2 of the 3 main points entry in terms of walking distance (metrically closer);
- Requires the same or fewer turns to reach the entry (has less syntactic depth) on both entry levels;
- Has a larger occupant load (is closer to more seating positions);
- Is directly visible from a larger area of the building (has a larger isovist area);

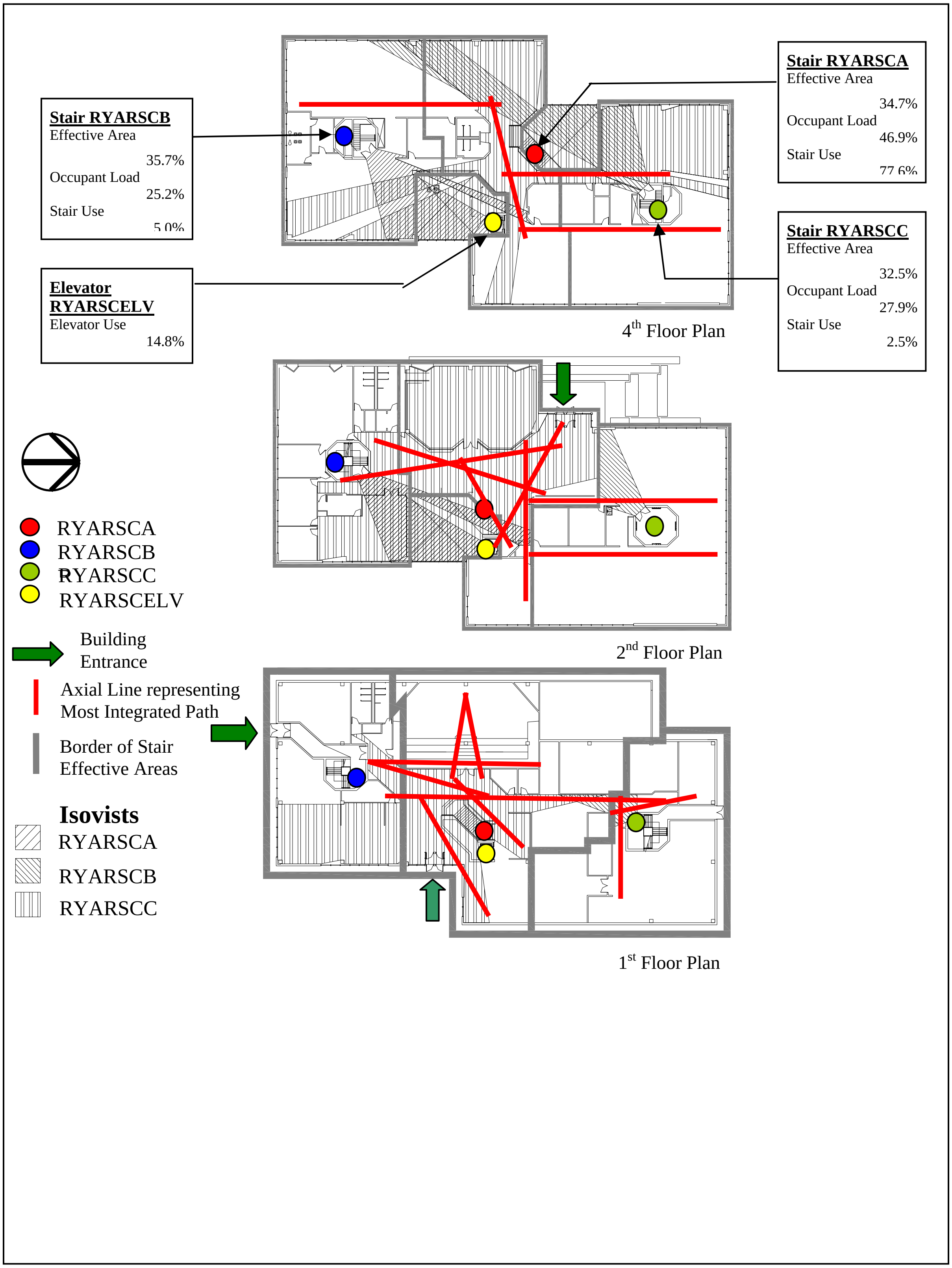


Figure 7.2 Building RYARSC
Graphic Representation of the Key Spatial Variables of Convenience & Legibility

Is visible from a larger area of the main hallway (has a larger isovist area on the most integrated path).

- Requires fewer turns to reach the MIP (has less syntactic depth from the most integrated paths)

Figure 7.2 indicates that unlike the previous case study of Building RYGCM, there is a significant overlapping of some of the key spatial variables onto the floor plans. The analysis of this graphic suggests that in some buildings, stair use may be influenced by the collective and comparative strength of each stair's spatial position relative to other stairs and elevators. The high use of Stair RYARSCA corresponds with its proximity and angular directness with two of the 3 building entrances and the MIP, the concentration of junctions of path segments of the MIP within the atrium lobby, and high occupant load spaces within both its effective area and its expansive isovist. The location of doorways to and from high occupancy and transitory spaces as studios, the library, lecture rooms and classrooms are located generally within the effective area of Stair RYARSCA. The clustering and intersection of many of the line segments of the MIP are primarily located with the effective area and isovist of Stair RYARSCA suggesting that most occupants within this building eventually travel near the visibly evident Stair RYARSCA. The graphic evidence explains why Stair RYARSCA attracts higher use than the nearby elevator whose further metric distance and the additional angular complexity from the high occupancy rooms and the wait times due to its limited cab capacity makes it a less convenient option for the movement of large social groups.

Figure 7.2 also provides graphical clues to understanding why Stairs RYARSCB and RYARCC receive so little use in comparison to Stair RYARSCA. In this case, neither the percentage of effective area or occupant load served by each stair forecast the proportional disparity between the use of the two stairs and Stair RYARSCA. This case implies the importance of the visibility of stairs in attracting travelers. It appears that the higher comparative visibility of Stair RYARSCA, whose expansive isovist extends over both its and the other stairs' effective area explains the substantial differences in use amongst the stairs in this building. Stairs RYARSCB and RYARSCC are enclosed staircases which have a limited visual presence within their immediate area except at their doorways. The stair doors, which are located on one of the 45-degree angle walls of the stair enclosure, make the stair entrances visible to only those entering the area from the central atrium. When their isovists are mapped onto the floor plan of the building, it is evident that their existing position makes the stair door visible within only a small area of the occupied space of the floor plan. In the case of Stair RYARSCB, the isovist extends primary across the uninhabited space of an opening within the lobby's atrium, rather than across an area where building occupants might see it from their work and travel areas. The isovist for Stair RYARSCC is quite confined to a small portion of the large studio and has minimal exposure to the MIP.

7.2.2 Building GTMARC

Building GTMARC has a high proportion (66.5%) of vertical travel within the building by stair use, concentrated primarily on a single stair. Stair GTMARCA, located in the central atrium, is used for 47.6% of all vertical travel. There are four other stairs in the building; all located within enclosed stairs wells at the ends of each of the building's long

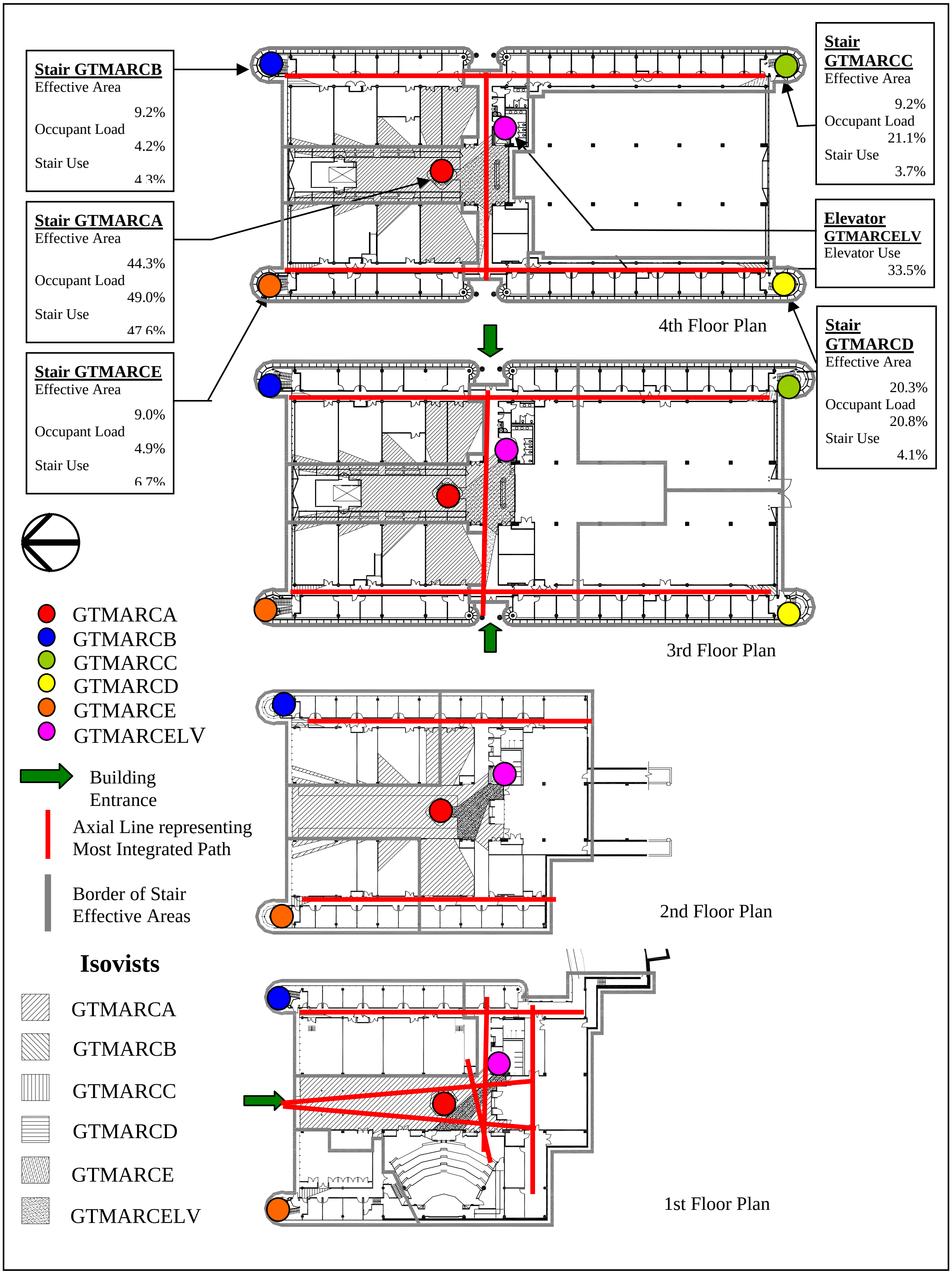


Figure 7.3 Building GTMARC
Graphic Representation of the Key Spatial Variables of Convenience & Legibility

corridors, which attract considerably less vertical travel. Stairs GTMARCB and GTMARCC which service four floors of the building account for 4.3% and 3.7% of vertical travel respectively. Stair GTMARCD and GTMARCE, which serve only the two upper floors of the building, account for 4.1% and 6.7% of vertical travel respectively. There is one elevator in the building located close to Stair GTMARCA, which attracts 33.5% of vertical travel.

Building GTMARC is an expansive 4-story building that accommodates a multidisciplinary manufacturing research center. The building is entered either on the first floor through a set of doors into the 4 story atrium. The building's large lecture theatre, classrooms are located directly next to the atrium on the ground floor. There are also faculty offices and laboratories on the first floor located along corridors on the each side of the building. Two other entrances are located on the third floor on either side of the lobby corridor that joins the two long corridors that extend the length of the building from the second to fourth floor. The third floor entrances provide access to people from campus buildings on each side of the building. Most of the building's function including faculty and administrative offices and laboratories are accessed from the public corridors servicing the second to fourth levels.

Stair GTMARCA has the following characteristics compared to the elevator and the other stairs in the building. It:

- Is closer to all main points entry in terms of walking distance (metrically closer);
- Requires the same or fewer turns to reach the entry (has less syntactic depth) on both entry levels;

- Has a larger effective area (is nearer a greater proportion of the floorplate);
- Has a larger occupant load (is closer to more seating positions);
- Is directly visible from a larger area of the building (has a larger isovist area);
- Is visible from a larger area of the main hallway (has a larger isovist area on the most integrated path).
- Is closer to the elevator in terms of walking distance (in feet)

Stair GTMARCA's location within the central lobby corridor provides the closest metric and angular proximity to all three entrances into the building. Stair GTMARCA has an expansive isovist that includes substantial portions of the MIP on the first floor and within the central lobby corridors on each level. The visibility of Stair GTMARCA is optimized by the extension of its isovist into occupied workplaces such as the laboratories on the second to fourth floor. The stair benefits as well by its proximity to the building's elevator.

The close proximity of Stair GTMARCA and Elevator GTMARCELV likely benefit both options for vertical travel although the stair appears to possess spatial characteristics that may explain why it attracts more users. The visibility of the elevator is limited both within the atrium and within the lobby corridor at every level of the building when compared to the adjacent grand stair GTMARCA. The placement of the elevator parallel to the direction of travel through the corridor means the elevator is decisively less visually apparent to travelers entering the lobby area from the east entrance. In addition, Stair GTMARCA obstructs the view of the elevator from the most places in the atrium including the entrance. However, there is one spatial factor that may support elevator use in this building. The elevator has the largest cab in the data set measured 56 square feet (sufficient to accommodate 18 persons) lessening the disadvantage that many elevators have in accommodating the movement of larger social groups through the building.

7.3 High Stair Use: Multiple Stair Strategy

Four buildings within the data set had high overall stair use (stair use accounting for more than 60% of vertical travel) resulting from a distribution of vertical travel between more than two stairs, each accounting for more than 15% of vertical travel within their building. Only one elevator serves each building. These buildings range in their buildings size, complexity and arrangement of their corridors and paths of travel, the number of stairs (2 to 6) and building height (3 and 4 levels). The case studies provided four cases where the placement of visually apparent stairs along the segment of a building's MIP that joins its main points of building entry results in both the distribution of stair use along this path but also overall high stair use in the building.

7.3.1 Building GTEL

Building GTEL is notable because it has a high proportion of users who take the stairs rather than elevator for vertical travel (stairs are used for 87.5% of vertical travel). In this building stair use is distributed primarily amongst four stairs in the building. A grand stair, Stair GTELA, attracts 18.9% of vertical travel. Stair GTELD is the best-used stair in the building accounting for 35.5% of vertical travel. Two other enclosed stairs, GTELB and GTELE account for 11.8% and 15.6% of vertical travel. There is only one elevator in the building, which attracts 12.5% of the vertical travel in the building. A freight elevator located

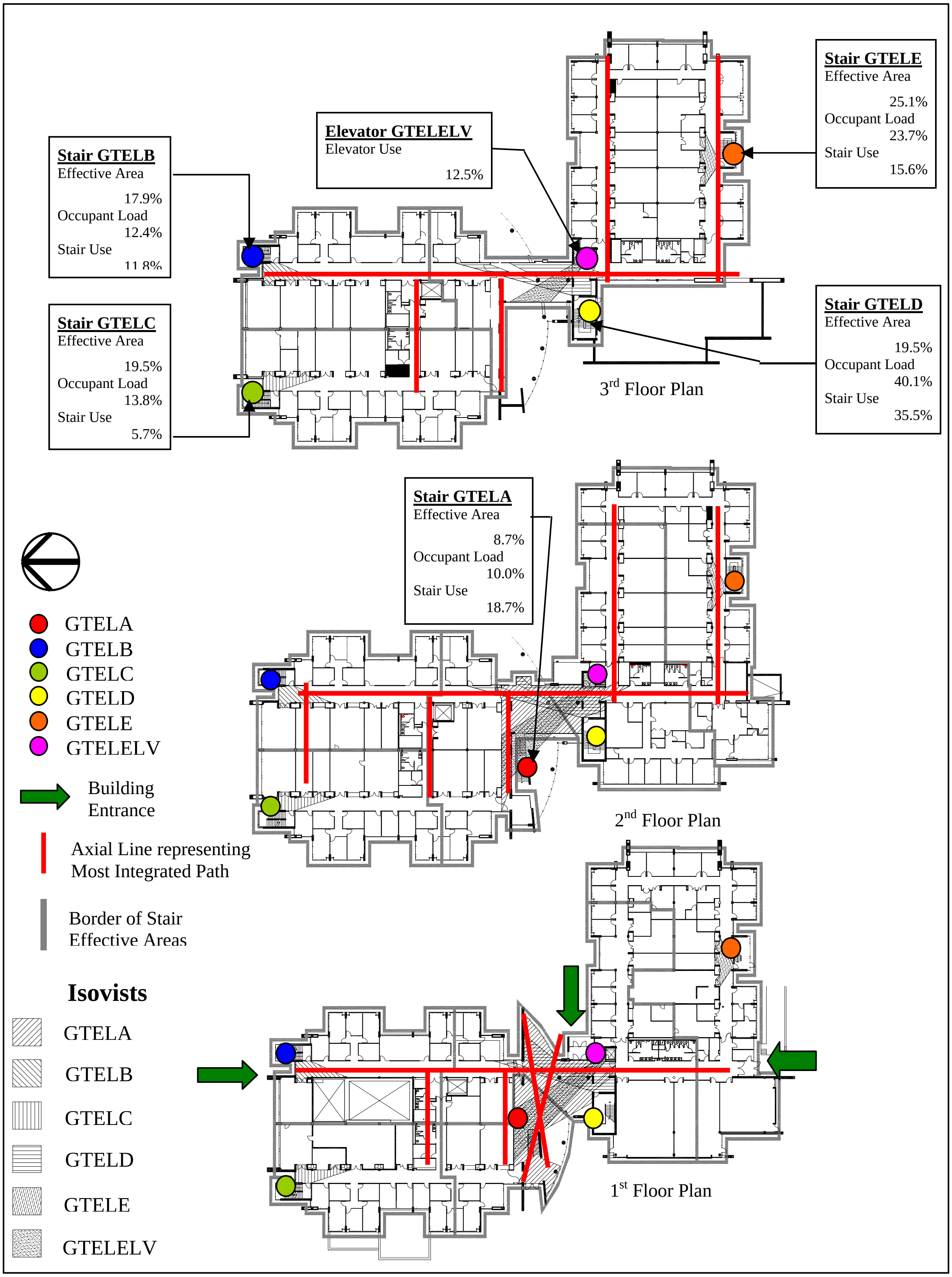


Figure 7.4 Building GTEL
Graphic Representation of the Key Spatial Variables of Convenience & Legibility

in the north wing is not available for passenger travel and was not in the scope of this study

Building GTEL contains two engineering programs, each contained on one of the 3-story building blocks, which are connected by a 3 level atrium to form a single building. The building contains laboratory spaces and faculty offices, although there are three large classrooms in the southern part of the building that serve students within the entire building. Stairs GTELB and GTELC are located within the north block of the building. Stairs GTELD and GTELE are located within the south block of the building. The building's central atrium contains a highly articulated grand stair, Stair GTELA, located in close proximity to the formal entrance doors on the east side of the atrium, and services only the ground to second floor. The entrance at the east end of the atrium is the formal entrance to the building, from which the street address is derived but it is also one of the least-used of the entrances. The building's passenger elevator is located near the west atrium entrance doors. People tend to enter the building from the west side of the building where other nearby engineering buildings are located. This results in an increasing importance on the corridor and segment of the MIP that connects the three most utilized entrances of the building and both program blocks of the building. This movement structure suggests that the organizing structural component of this building is this north-south corridor.

In the previous chapter, stair use was associated with stairs that were articulated or grand stairs. In this building stair use, 69.8% of vertical travel occurs along the north-south corridor where modestly finished and enclosed Stairs GTELB, GTELD and the elevator are located. These stairs and elevator share the following characteristics over other stairs in the building:

- Proximity (in metric travel distance and angular complexity) to the key path segment(s) of the MIP that connect the building's entrances
- Visibility along the path segments of the MIP that connect the building's entrances (the length of key path of the MIP visible from the stair isovist)
- Visibility of stair from the junction points of paths of the MIP that link the patterns of movement within the building to the stair (the divergence of the configuration of the MIP from the stair)

The distribution of occupant load and the presence of densely populated programmed areas are generally consistent with stair use patterns within the building. The exception is the low level of stair use for Stair GTELC, located furthest from the north-south corridor. However when effective areas, occupant loads and stair use for Stair GTELC and the closest stair, Stair GTELA are compared (the combined collective effective areas (28.2%), occupant loads (23.8%) and stair use (24.6%), it is apparent that Stair GTELA maybe be attracting its users primarily from occupants from the west side of the building.

Stair GTELD, a compartmentalized and basically finished stair receives twice the stair use of the highly articulated and uniquely detailed grand stair GTELA. Stair GTELD, the best-used stair in the building, has the following characteristics compared to the nearby Stair GTELA. It:

- Is closer to all main points entry in terms of walking distance (metrically closer);

- Requires the fewer turns to reach all points of building entry (has less syntactic depth)
- Has a larger effective area (is nearer a greater proportion of the floorplate);
- Has a larger occupant load (is closer to more seating positions);
- Is directly visible from a larger area of the MIP that connects the three building entrances (has a larger isovist area on the most integrated path).
- Is closer to the elevator in terms of walking distance (in feet)

Stair GTELA is oriented such that lowest step (the entry and discharge point) is oriented towards the less frequently used formal entry door rather than the well-used entrance on the other side of the atrium. This makes the path of travel to Stair GTELD less angular complex than that for Stair GTELA from both the main entry and the most integrated path. Stair GTELA has a large solid 6-foot high artistic display wall on its south side, which obscures the view of its entry lowest steps from the most-used entrance at the east side of the atrium. Although Stair GTELD is an enclosed stair with fairly basic level of finishes, its entry door into the stairwell is held open with an electronic hold-open device, allowing a direct view of the entry flight from most of the length of the most integrated path near the main entrance.

Stair GTELD also receives more use than the adjacent elevator. Stair GTELD’s 75-inch stair width and close proximity of the concentrated occupant load from the large classrooms along the south end of the corridor likely enhances its desirability for timely vertical travel over the elevator which can only accommodate about seven persons. Although both have close metric proximity the building entrance and MIP, the elevator has low visibility compared to Stair GTELD from both the entrance and the MIP. The elevator isovist projects deep with the atrium but has only a short period of interaction along the key segment of the MIP due to the positioning of the elevator door to the side of the elevator vestibule. The elevator is therefore not as visible from the numerous directions of travel within the north-south corridor and atrium as Stair GTELD.

7.3.2 Building RYINT

Building RYINT has a high proportion of users who take the stairs rather than elevator for vertical travel (stairs are used for 72.9% of vertical travel). In this building stair use is distributed between the two stairs in the building: Stair RYINT attracts 50.8% of vertical travel and Stair RYINT, which accounts for 22.1% of vertical travel. There is only one elevator in the building, which attracts 27.1% of vertical travel in the building.

Building RYINT is a renovated 3-story building originally built circa 1920 as a factory, which now houses a school of interior design. A workshop, library and administrative office occupy the first floor. The second and third floors accommodate large studio spaces, classrooms, and faculty offices. This is a secured building in which access is only permitted by access card issued to all program students, faculty, and staff or by an automated door lock that requires visitors to page administrative staff over a intercom prior to allowing entry. The building has two principal entrances, which are both well-used. One entrance, which is located on along the main street, allows entry into the main lobby area of the building. Immediately adjacent and located within the vestibule of the entrance is Stair RYINTA. This stair is separated from the main lobby on each floor by a fully glazed screen.

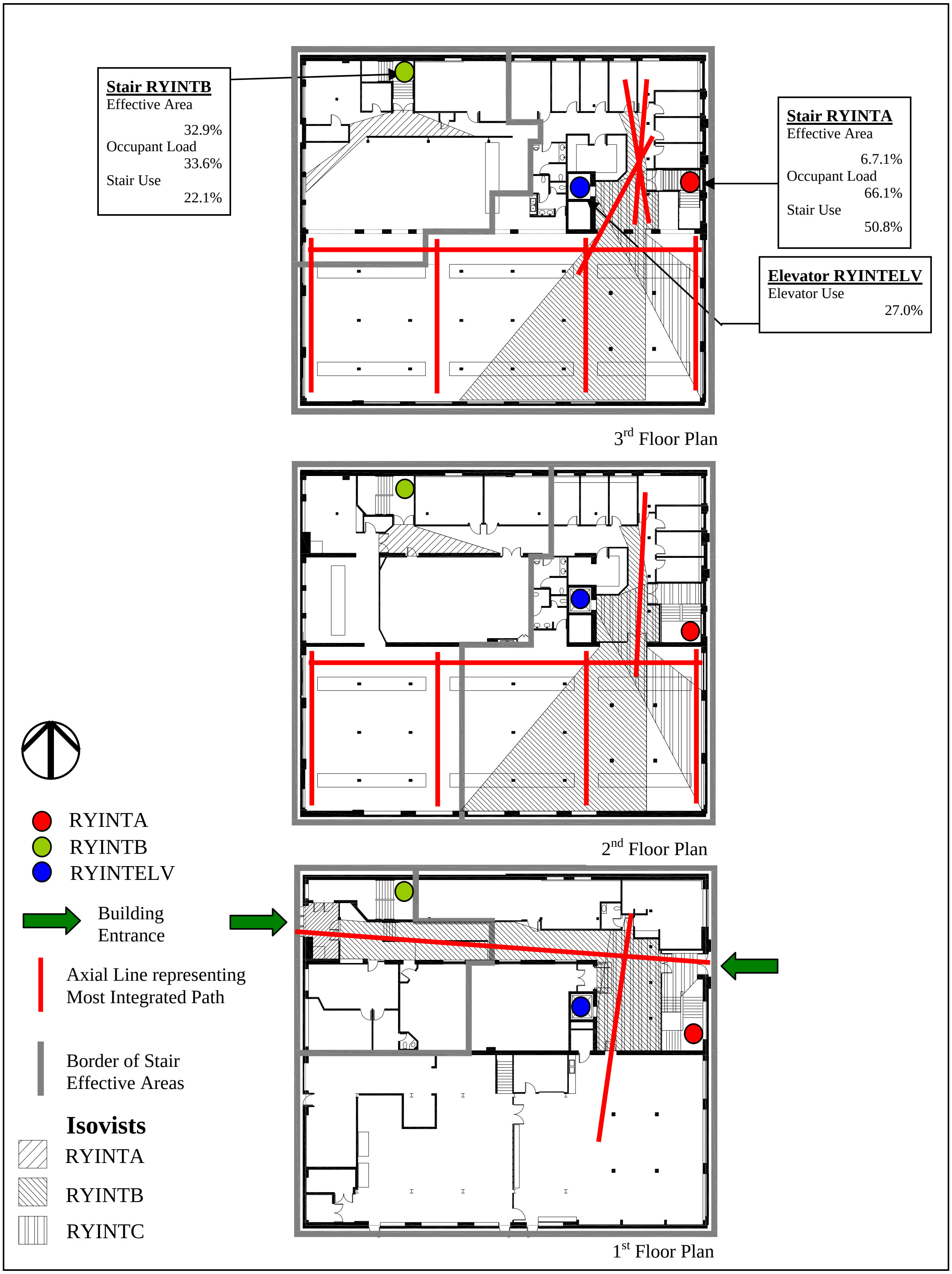


Figure 7.5 Building RYINT
Graphic Representation of the Key Spatial Variables of Convenience & Legibility

The building's only elevator, Elevator RYINTELV, is located within the lobby. At the opposite end of the building is another building entrance, which connects this building through a back lane to the majority of buildings on the campus. Stair RYINTB, which is located within the entrance vestibule on the ground floor, is accessible on the second and third floor from a public corridor that services the classrooms and offices on each floor. Building RYINT possesses a movement structure related to stair use pattern similar to Building GTEL, comprised of the building's entrances, the MIP and the isovist of stairs and elevators. Both stairs in the building have the following collective features:

- Proximity (in metric travel distance and angular complexity) to the key path segment(s) of the MIP that connect the building's entrances
- Visibility along the path segments of the MIP that connect the building's entrances (the length of key path of the MIP visible from the stair isovist)
- Visibility of stair from the junction points of paths of the MIP that link movement within the building to the stair (the divergence of the configuration of the MIP from the stair)

Differences in stair use between the two stairs may be related to minor variations in floor layouts between the floor levels, which result in significant differences in the configuration of the MIP on the first floor when compared to the second and third floor levels. On the first floor, both stairs are visible, in close proximity, and have limited angular complexity to the segment of the MIP that connects both entrances. However on upper levels Stair RYINTB is metrically and syntactically remote from the MIP which tree-like configuration connects the building's lobby area with the studio area where 66.1% of the occupant load of the building is located.

Like other examples of high performing stairs, Stair RYINTA has the following characteristics, it:

- Is close to the main entry in terms of walking distance (metrically closer);
- Requires the fewer turns to reach all points of building entry (has less syntactic depth)
- Has a larger effective area (is nearer a greater proportion of the floorplate);
- Has a larger occupant load (is closer to more seating positions);
- Is directly visible from a larger area of the building (has a larger isovist area);
- Is visible from a larger area of the main hallway (has a larger isovist area on the most integrated path).
- Is closer to the elevator in terms of walking distance (in feet)

Although also located within the building lobby, Elevator RYINTELV receives half the use of the adjacent Stair RYINTA. This may be due to several factors including its smaller capacity, lesser exposure to the MIP and limited the studio workspaces due to direction of its isovist compared to Stair RYINTA. Although the studio space is not densely populated, mass exiting from this area at the end of a class may result in a concentrated occupant load within the lobby area making the stair a timelier means of exiting.

Stair RYINTB, in spite of its limited exposure to the MIP on the upper levels of the building, accounts for 25% of vertical travel in the building. While the stair's relationship with the MIP at the entry level has a role in distributing stair between the two floors in the building, Stair RYINTB would likely have lesser use if not for its visibility and metric proximity to doorways of high occupant load spaces such as the classrooms which are adjacent to Stair RYINTB to compensate its less integrated location on the second and third floors of the building.

7.3.3 Building GTUAW

Building GTUAW also has a high proportion of users who take the stairs rather than elevator for vertical travel (stairs are used for 76.0% of vertical travel). In this building, stair use is distributed between the two of the three stairs in the building: Stair GTUAWA attracts 58.6% of vertical travel and Stair GTUAWB, which accounts for 20.6% of vertical travel. The other stair in the building receives considerably less used, attracting only 4.2% of vertical travel. There is only one passenger elevator in the building, which attracts 22.0% of vertical travel in the building. A freight elevator, which is not permitted for passenger travel is located near Stair GTUAWC, was not included in this study.

Building GTUAW is a three-story biomedical engineering program building, which contains secured laboratories, and faculty offices available to authorized students and faculty on each level. The publicly accessible spaces in the building, which include a large classroom, several small seminar rooms and the administrative offices, are located on the first floor of the building. The building has several points of entry, which are accessible along the long first floor lobby, but most building users enter from one principle point of building entrance at the first floor level. Another entrance to the building is from a bridge on

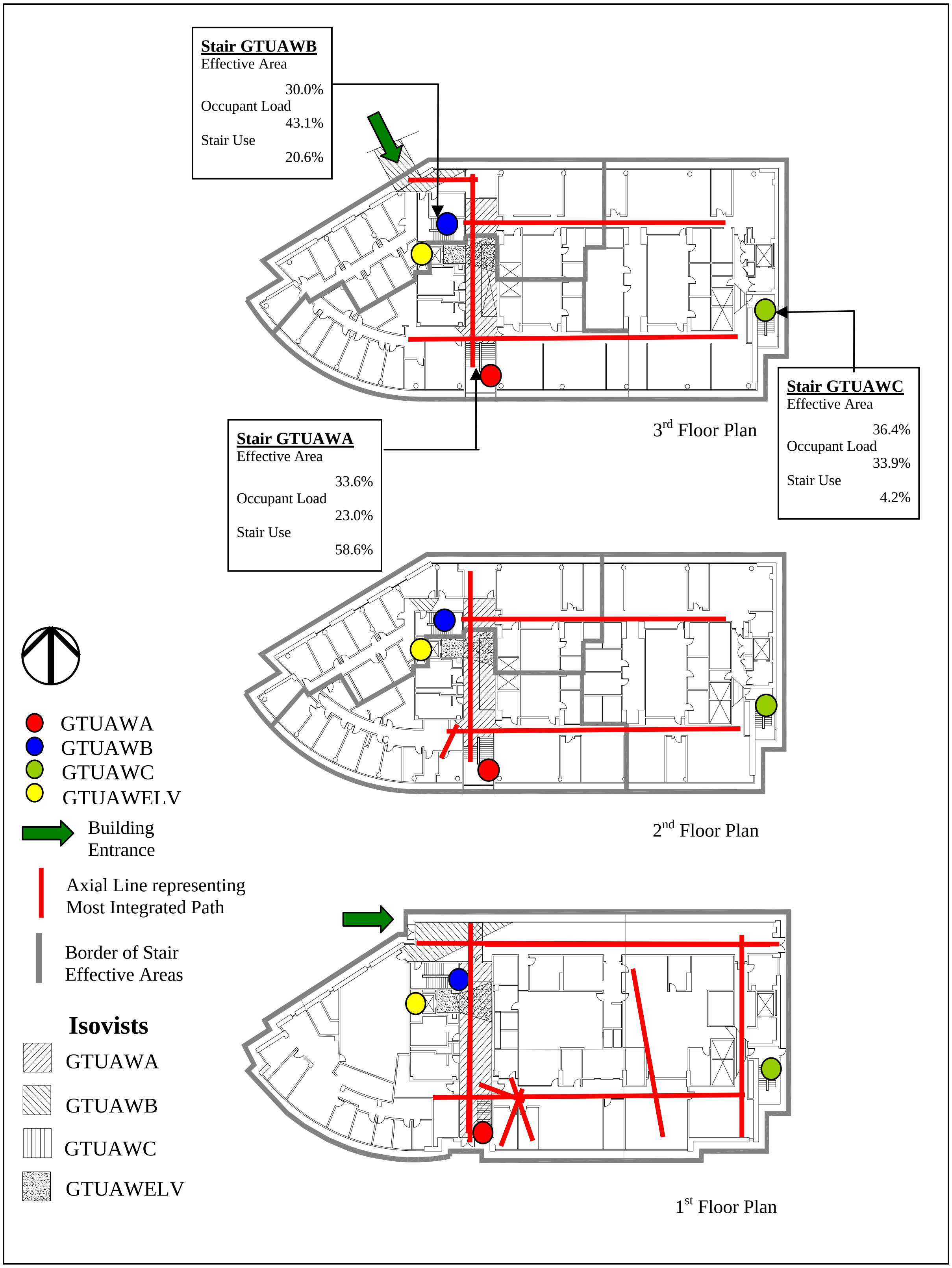


Figure 7.6 Building GTUAW
Graphic Representation of the Key Spatial Variables of Convenience & Legibility

the third floor which Building GTUAW connects with Building GTIBB (Note 4). The entry door along the street from which the building's street address is derived is accessible by card reader only and (similar to the formal street entrance for Building GTEL) is remote from where building users actually approach the building. Building GTUAW possesses the composite spatial structure comprised of the building's entrances, the MIP and the isovists of stairs and elevators identified in previous case studies within this strategy. Stairs GTUAWA and GTUAWB have the following collective features:

- Proximity (in metric travel distance and angular complexity) to the key path segment(s) of the MIP that connect the building's entrances on the first and third floor;
- Visibility along the path segments of the MIP that connect the building's entrances (the length of key path of the MIP visible from the stair isovist);
- Visibility of stair from the junction points of paths of the MIP that link the patterns of movement within the building to the stair.

In addition to above, Stair GTUAWA, the best-used stair in the building, has the following characteristics compared to the elevator and the other stairs, many of which are common to the best-used stairs in other buildings. It:

- Requires the same or fewer turns to reach all points of building entry (has similar or less syntactic depth);

Note 4: Construction of the bridge connecting Buildings GTUAW and GTIBB was not complete during data collection of Building GTIBB in Fall 2003. The bridge was available in Spring 2004 when data collection in Building GTUAW was conducted.

- Is directly visible from a larger area of the building (has a larger isovist area);
- Is visible from a larger area of the main hallway (has a larger isovist area on the most integrated path);
- Requires fewer turns to reach the MIP (has less syntactic depth from the most integrated paths).

Stair GTUAWB has a relatively high level of use (20.6 % of vertical travel) for an enclosed star with a modest level of interior finish. This stair however is strategically placed and visually evident at the both points of the building entry and it forms the shortest, most direct route through the building from either entrance to the faculty and administrative offices. It also benefits from its proximity to the high occupant load of the large classroom on the first floor.

Stair use patterns in this building are also impacted by the limited accessibility of Stair GTUAWC. The public portions of this building are limited, as most of the laboratory spaces required an entry card for access. Stairs GTUAWA, GTUAWB and the elevator serve public areas of the building at all levels. Stair GTUAWC however, is accessible above the first level only to those with access authorization into the laboratories, thus restricting its use primarily to a means of building egress. Stair GTUAWC's low stair use is consistent with other stairs in this study that have low occupant loads and are located metrically and visually remote from junctions within the MIP and the building's entrance. In a similar manner as observed in Buildings GTEL and RYARSC, the highly visibly grand stair appears to expropriate the occupant load of visibly and metrically remote stairs.

The passenger elevator GTUAWELV located in the main central lobby accounts for 22%, less than half the use of the adjacent Stair GTUAWA. The lower frequency of elevator use when compared to the use of an adjacent stair is consistent with observations in previous case studies such as Buildings GTEL and GTMARC. In all these cases, the elevators are less visible from the MIP. Their placement limits the size and direction of its isovist and increases the number of turns required for access from the MIP when compared to extensive exposure and minimal angular complexity from the MIP of an adjacent stair.

7.3.4 Building GTCOA

Building GTCOA has a high proportion of users who take the stairs rather than elevator for vertical travel (stairs are used for 87.1% of vertical travel). In this building stair use is distributed primarily amongst three of the six stairs (over 15% vertical travel use each) in the building. Stair GTCOAA, a grand stair located in the building atrium, attracts 33.1% of vertical travel. Stair GTCOAD attracts 17.5% of vertical travel and Stair GTCOAE accounts for 19.0% of vertical travel in the building. Stair GTCOAB, an exterior stair, receives 11.9% of vertical travel. Two other less-used stairs, GTCOAC and GTCOAF account for 4.3% and 0.3% of vertical travel. There is only one elevator in the building, which attracts 12.9% of vertical travel in the building.

Building GTCOA is a large 4-story building that accommodates several academic programs including architecture, city planning and industrial design. Building GTCOA is comprised of two building: an original 4-story building on the east side, which has its

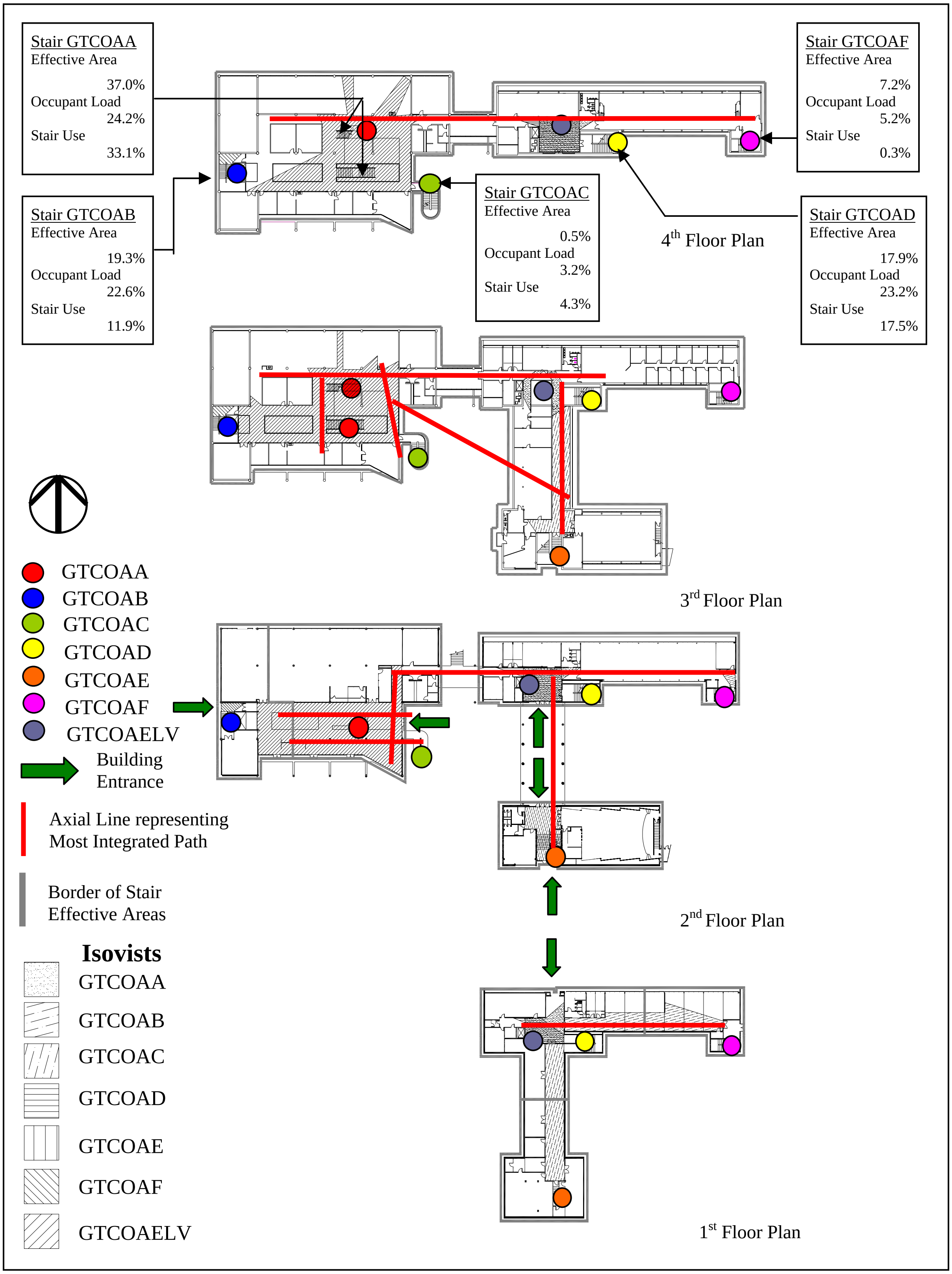


Figure 7.7 Building GTCOA
Graphic Representation of the Key Spatial Variables of Convenience & Legibility

functional spaces arranged within long narrow wings which maximizes light and views from the studios and offices to outside courtyards and building exterior and a 3 story addition to the west side which, locates the functional spaces around the perimeter of the building allowing for both light and views of the buildings exterior environment and the activities within the building's large interior atrium. The two building are connected by a bridge at the second and third floors only, resulting in travel through the exterior courtyards between the two buildings for journeys at the ground level. There are 6 stairs in this building and one elevator serving the first to fourth floor of this building. Stairs serving minor changes in grade in the auditorium or to the 4th floor mezzanine are not including in the scope of this study.

Stairs GTCOAA, GTCOAD and GTCOAE share common spatial characteristics observed in previous case studies:

- Proximity (in metric travel distance and angular complexity) to the key path segment(s) of the MIP that connect the building's entrances on the first and third floor;
- Visibility along the path segments of the MIP that connect the building's entrances (the length of key path of the MIP visible from the stair isovist);
- Visibility of stair from the junction points of paths of the MIP that link the patterns of movement within the building to the stair.

In addition, these stairs share the following characteristics when compared to the other stairs and elevator in the building. They

- Requires the same or fewer turns to reach the closest building entry (has similar or less syntactic depth)
- Are visible from a larger area of the main hallway (has a larger isovist area on the most integrated path).
- Are directly visible from a larger area of the MIP that connects the building entrances (has a larger isovist area on the most integrated path).

This building illustrates some inconsistency with the spatial relationship between stair use and the proximity of the stairs and the elevator. The statistical analysis in Chapter 6 identified that stair use increased with proximity to the elevator. However in this building, the provision of only one elevator within the building's expansive floor plan appears less importance to stair use than the proximity of stairs to building entrances. Stairs GTCOAA and GTCOAB within the west part of the building while also possessing other key spatial factors likely benefit from their remoteness and thus lack of spatial competition with the elevator. When a stair and an elevator share proximity, the relationship may be more symbiotic. In this building, the elevator, which receives 12.9% of vertical travel, receives slightly less use than the nearby Stair GTCOAD (17.5%). This may be related to several factors: 1) its less visible and more angularly complex position in respect to the paths of travel along the on MIP (especially on the third floor); and 2) its proximity to high occupancy rooms such as the classrooms and studios which make the elevator's cab size and waiting times less compatible with the movement of groups than the wide adjacent Stair GTCOAD. This suggests that additional issues of proximity between stairs and elevators are worth investigating in future research including if there is a maximum distance that people are willing to travel to an elevator before it is too remote to be considered as an alternative option for travel.

7.3 Lower Stair Use Buildings

The following analysis examines three buildings with lower levels of stair use ($\leq$60% of vertical travel). These buildings range in their buildings size, complexity and the arrangement of their corridors and paths of travel, and the number of stairs (2 to 5) and building height (3 and 4 levels). Two of the three building have two elevators. The case studies indicate that incompatible arrangement of the key spatial variables result in lower levels of stair use.

7.4.1 Building GTIBB

Building GTIBB is noteworthy because despite having six stairs, stair use accounts for only half of vertical circulation within the building. Three stairs, located at the exterior wall of the laboratory wings, GTIBBD (4.4%), GTIBBE (2.6%), and GTIBBF (3.2%) receive little use. A grand stair located in the atrium attracts 32.8% of vertical travel. There are two enclosed stairs located within the interior floorplate, Stairs GTIBBB and GTIBBC, which attract 1.1% and 8.5% of vertical travel respectively. The building has two elevators located adjacent to each other that attract 47.4% of vertical travel.

Building GTIBB is a large 3-story building that accommodates a multi-disciplinary program in biotechnology and bioscience. The building has three wings that accommodate laboratories, which have restricted access to each floor of a laboratory (from

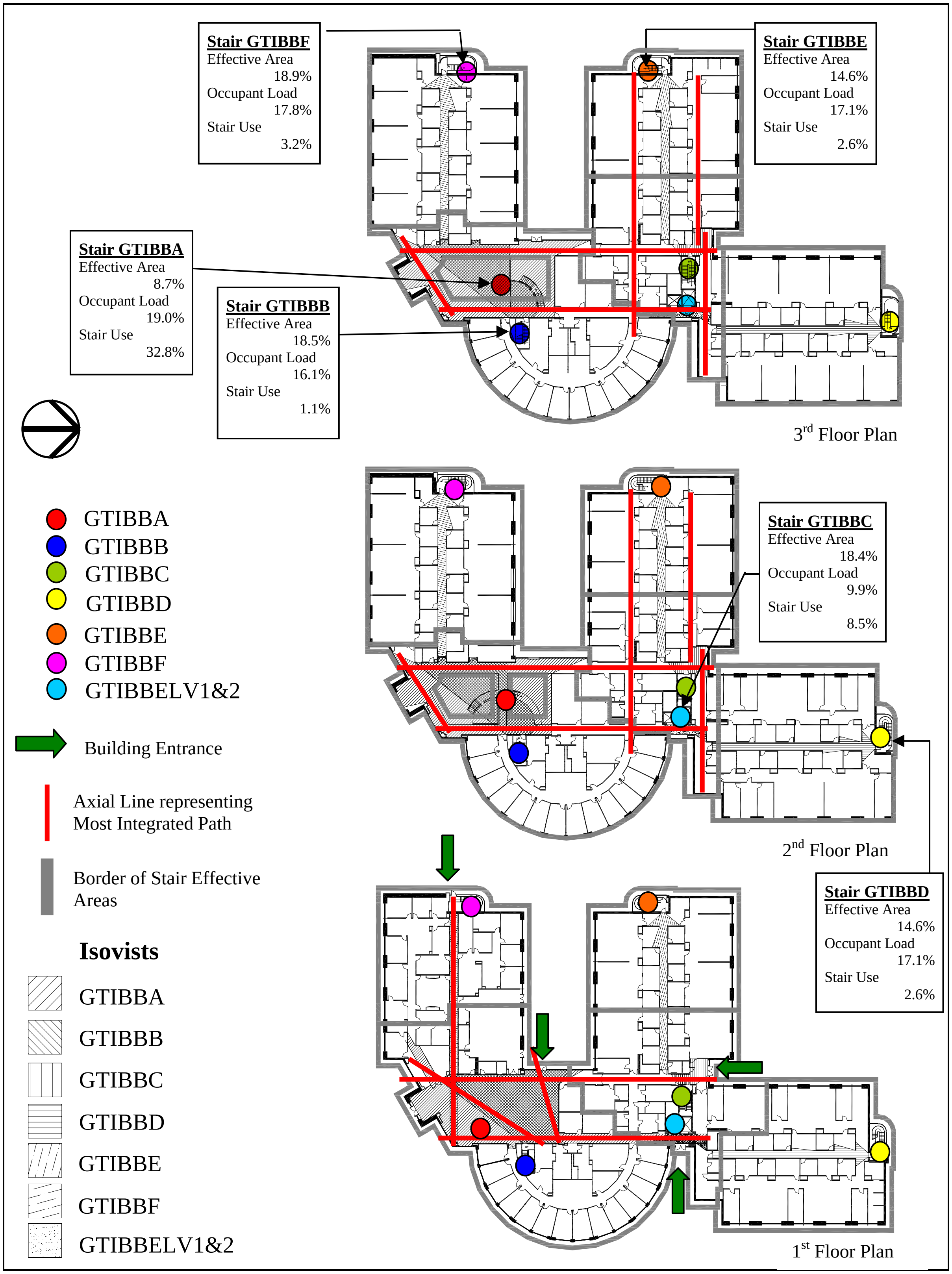


Figure 7.8 Building GTIBB
Graphic Representation of the Key Spatial Variables of Convenience & Legibility

both the public corridors and staircases) to authorized personnel only. Each of the laboratory wings has a stairwell (GTIBBD, GTIBBE, and GTIBBF) at the perimeter of the building floor plan. These stairwells, which are enclosed in a glass and aluminum enclosure, are a highly visible feature of the building's exterior. The program administrative offices for the building are located on the 1st floor of the laboratory wing closest to the building's atrium. Faculty offices are located within the semi-circular wing adjacent to the building's atrium. The building has a large 3-story atrium, which contains an elegant and expansive spiral staircase, Stair GTIBBA. This stair is the closest stair to the south laboratory wing, which also contains the administrative offices, faculty offices, a lecture theater, and café on the first floor level. Two basically finished enclosed stairs are also located within the public area of the building and provide access to all levels of the building. Stair GTIBBB is located immediately adjacent to the grand Stair GTIBBA. Stair GTIBBC is located along the public corridor system near both an entrance adjacent to a nearby parking structure and between two of the laboratory wings. One design feature of this building that is unique to other buildings in this data set is the location of the building's elevators. The elevators are not located in close proximity to or are visible from the atrium lobby where the main entrance to the building is to be located. However, construction of a nearby Building GTUAW resulted in the closure of the main entrance of the building on the south side of the atrium and the diversion of traffic towards the exterior doors immediately adjacent to the elevators. Thus travel patterns in the building observed in this study will likely differ from what may be expected once construction was complete and the building's south main entrance and a third floor bridge to Building GTUAW is opened.

In this building, two stairs, Stairs GTIBBA and GTIBBC and the two elevators account for 88.7% of all vertical travel. These stairs and elevators share the following characteristics over the other stairs in the building (with the exception of Stair GTIBBB which will be discussed later):

- Proximity (in metric travel distance and angular complexity) to the key path segment(s) of the MIP that connect the building's entrances;
- Visibility along the path segments of the MIP that connect the building's entrances (the length of key path of the MIP visible from the stair isovist);
- Visibility of stair from the junction points of paths of the MIP that link the patterns of movement within the building to the stair.

The low stair use of Stairs GTIBBD, GTIBBE, and GTIBBF can be understood by their spatial characteristics. Although they are highly visible from the exterior of the building, their presence is almost indiscernible from within the interior of the laboratory space. Figure 7.8 illustrates that their limited isovists have no interaction with the MIP of the building. It is evident that stair use is a product of the organization of interior space within a building; high visibility and imageability from the exterior cannot overcome unintelligibility in location within the interior layout of a building.

The set of elevators located along the east corridor accounts 47.4% of vertical travel within the building. Although not located within the building's atrium, they are located close to the two principal entrances and in close proximity to two of the three laboratory wings. Stair GTIBBC may receive less benefit from its proximity to the elevator due to its number of turns required for travel between the stair and elevator and the provision of two elevators lessens the waiting time for an elevator.

Stair GTIBBB presents an anomaly within this study. This stair possesses many of the key characteristics of well-used stairs such as Stair GTIBBA, yet attracts only 1.1% of vertical travel. This stair is an enclosed fire stair with a basic level of finishes located adjacent to the highly articulated spiral stair, Stair GTIBBA. While the main finding of this study suggests that location rather than appearance best explains stair use in buildings, this case study suggests that when the key spatial features of two stairs are generally similar, imageability plays a decisive role in choice.

7.4.2 Building RYENG

Building RYENG is notable because it has relatively high elevator use (40.0% of vertical travel) when compared to other buildings in this study. The building contains four stairs. Two of the stairs, Stair RYENGA that attracts 37.2% of the vertical travel, and Stair RYENGB that attracts 20.3% of vertical travel, account for most the stair use in the building. The two other stairs, Stairs RYENGC and RYENGD receive little use, accounting for only 1.3 and 1.2% of vertical travel respectively. The building has two elevators, which collectively attract 40% of vertical travel. A freight elevator, which is not permitted for passenger travel is located near Stair GTENGC, was not included in this study.

Building RYENG, built in 2004, accommodates multiple engineering programs including electrical and computer engineering, computer science and aerospace engineering.

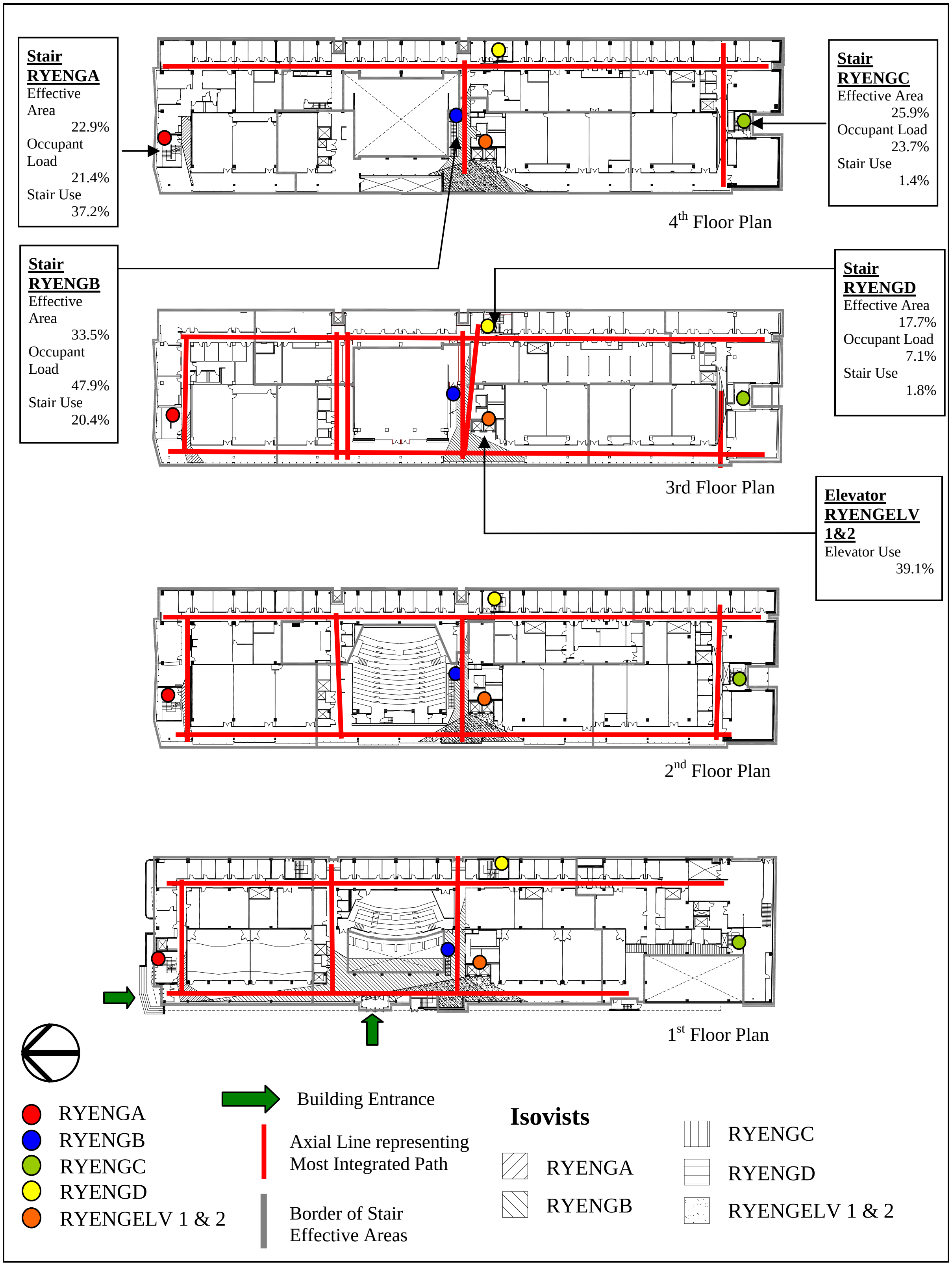


Figure 7.9 Building RYENG
Graphic Representation of the Key Spatial Variables of Convenience & Legibility

Although the large building in square area within the data set, there are only two publicly accessible entrances and four stairs which service the first to fourth floors of the building. As illustrated in Figure 7.9, a key feature of the building layout is the arrangement of functions relative to the public corridors. The pubic spaces of the building including classrooms and laboratories are located along the west corridor. The private spaces of the building which include private faculty offices are located along the east corridor. The east and west corridors are linked along the length of the building by four intermediate corridors. In the central area of the floorplate adjacent to the large lecture halls and presentation galleries is the elegantly detailed grand staircase, Stair RYENGB and two adjacent passenger elevators. Stair RYENGB and the elevators face the wide west corridor that runs the length of building on most floors. Both main entrance doors to the building are located along the west corridor as well. The entrance at the end of the west corridor (at the corner of the building) receives the majority of entrance travel into the building due to location at a traffic intersection.

Stairs RYENGA is a minimally finished enclosed stair located closest to the best used entrance to the building. Stair RYENGA, which is the best-used stair in the building has the following characteristics compared to the elevator and the other stairs in the building. It:

- Is closer to all main points entry in terms of walking distance (metrically closer);
- Has a larger effective area (is nearer a greater proportion of the floorplate);
- Has a larger occupant load (is closer to more seating positions);
- Is directly visible from a larger area of the building (has a larger isovist area);
- Is visible from a larger area of the main hallway (has a larger isovist area on the most integrated path) than the other enclosed stairs

- Has a wider stair width

This building actually displays many of the spatial characteristics of many high stair use buildings (multiple stair strategy) discussed in the earlier section. Stairs RYENGA and RYENGB share many of the spatial characteristics possessed by other well-used stairs including:

- Proximity (in metric travel distance and angular complexity) to the key path segment(s) of the MIP that connect the building's entrances
- Visibility along the path segments of the MIP that connect the building's entrances (the length of key path of the MIP visible from the stair isovist)
- Visibility of stair from the junction points of paths of the MIP that link the patterns of movement within the building to the stair (the divergence of the configuration of the MIP from the stair)

Although the building has overall good stair use, 60% primarily from Stairs RYENGA and RYENGB, several spatial factors appear favor elevator use as well. The spatial structure that best explains the frequency of stair and elevator use is evident within the first floor plan. There are two elevators in this building located close to a main entrance, a feature observed in the previous case study of Building GTIBB that appeared to increase elevator use. In this building the elevators more visible from the buildings entry and the key segment of the MIP that links the other entrance than the grand Stair RYENGB. Stair RYENGB is barely wider (47") than the minimum requirement of an exit stair, thus offering little advantage for travel in large social groups when one considers the added capacity and reduced waiting times provided by the two elevators.

Stairs RYENGC and RYENGD are visually, metrically and syntactically remote, especially on the first floor. This increases the number of people on the south and east portion of the building who will travel to the area around the elevator for vertical circulation. The lack of access into Stair RYENGD at the first floor level results in occupants of the east office corridors using other options than Stair RYENGD for vertical travel.

7.4.3 Building RYMON

Building RYMON has the lowest stair use (39.9%) in the data set; the only building with more elevator use than stair use. The building has two stairs, Stair RYMONA, which attracts 27.0%, and Stair RYMONB, which attracts 12.8% of vertical travel. There has one elevator, which receives 60.1% of all vertical travel within the building.

Originally built in 1920's to accommodate a newspaper business, the building was extensively renovated in the mid 1990's for use by an engineering program. The original stairs remain unchanged but a new elevator was added and the interior floor layout of spaces was revised to accommodate offices, computer laboratories on the 2nd to 4th floors with laboratories on the ground floor. Security concerns related to the building's location at the edge of the campus with an urban environment resulted in a decision to change the location of the main entrance to the building from its previous location, adjacent the grand Stair RYMONB, to the back lane of the building at the opposite side of the building. The stair and

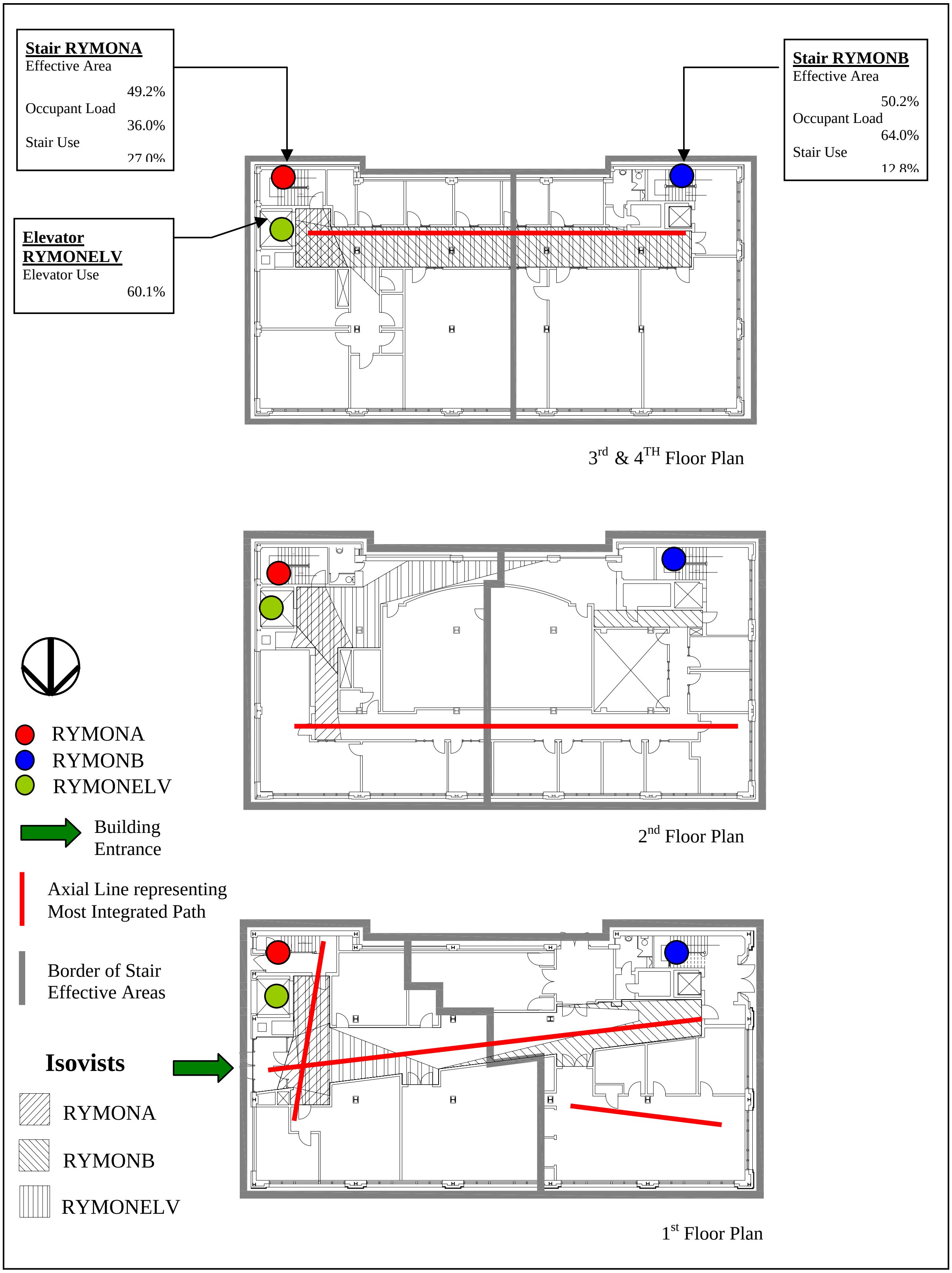


Figure 7.10 Building RYMON
Graphic Representation of the Key Spatial Variables of Convenience & Legibility

former entrance remained but is now locked, allowing for only for building egress. A new elevator was constructed within the new entrance lobby area adjacent to Stair RYMONA at the opposite side of the building. Neither stair was changed from its original appearance, such that Stair RYMONA located adjacent to the elevator is minimally finished in comparison to the grand marble-finished Stair RYMONB. Both stairs are narrower than current regulatory standards for new construction.

While other high stair use buildings illustrated clear and non-contradictory approaches to the arrangement of the stairs and elevators within the interior layout of building in relation to the spatial variables of convenience and legibility, Building RYMON perhaps offers a lesson in how contradictions within arrangements of the key spatial variables compromises the potential for stair use and can promote use of the elevator. Figure 7.10 indicates that Elevator RYMONELV and Stair RYMONA, which account for 87.2% of all vertical travel within the building, share several of the spatial relationships that were evident in the highly used stair in the previous case study. Both Elevator RYMONELV and Stair RYMONA are:

- located in close proximity to the building entrance:
- have isovists that interact with the junction of path segments of most integrated paths within the entrance lobby.

There is little difference in the proximity, visibility and angular complexity between the stair and the elevator from the building entrance from the first floor level although the elevator has a higher level of visibility along the extent of the MIP at the 3rd and 4th floor. It appears that when the key spatial variables of the elevator are similar or slightly better than the adjacent enclosed stair, especially one with the low imageability of Stair RYMONA, the elevator will likely prevail as the desirable option for vertical travel. Building RYMON does not contain a large occupant lecture hall, which minimizes the size of groups that generally move within the building. Elevator RYMONELV may be able to effectively and comfortably accommodate the movement of socially engaged groups better than Stair RYMONA whose very narrow width, low imageability, low level of maintenance reduce its desirability as a comfort option for travel.

The use of Stair RYMONB is also influenced by several spatial variables such the distance from both the entrance and elevator, its additional complexity in the turns from MIP and the entrance, restricted physical accessibility, and its narrow stair width that limit its desirability to use. While it possesses positive features such as high imageability and the larger percentage of occupant load within its effective area, its remoteness from the key spatial structure (that combines the isovist of a stair along the path segment of the MIP that connects with the principal entrance) appears to reduce its desirability for travel. Its high imageability can not overcome visually, metric and syntactic remoteness.

7.5 Chapter Summary

The graphic analysis of the ten academic buildings provided compounding evidence that a set of key spatial measures of convenience and legibility identified within the multiple stages of this study is associated with stair use within workplace buildings. The relationship between stair use and the individual spatial variables identified in this study is summarized as follows. Stairs generally receive more use when they:

- Are metrically closer to the building entrance;
- Are metrically close to the elevator (although in buildings with long floor areas, stairs located close to building entrances and the MIP may benefit from remoteness to the elevator);
- Have a larger effective area (greater proportion of the floor area);
- Have a larger occupant load (closer to where more people work);
- Are directly visible from a larger area of the building (have a larger isovist area);
- Are visible from a larger area of the main hallway (has a larger isovist area on the most integrated path) and where people work;
- Requires fewer turns to reach the closest building entrance (has less axial depth from the entrance);
- Requires fewer turns to reach the MIP (has less axial depth from the most integrated paths)
- Can accommodate people traveling in small social groups (have a wide stair width)

In addition to the above, the graphic analysis study offered some lessons about physical environmental factors, which were not previously identified in earlier stages of the study. They include:

- The provision of more than one elevator can reduce stair use by lessening the two key factors of inconvenience to elevator use, wait times and limited capacity to accommodate social groups

- The visibility of stairs from the exterior of the building did not related to be an influence on stair use. Stair use is related to spatial relationships within the building.

This analysis observed a key spatial structure associated with the two strategies for high stair use observed in this study. The primary difference that distinguishes the two strategies for high stair use is the number of stairs located:

- In close proximity (in metric travel distance and angular complexity) to the key path segment(s) of the MIP that connect the building's entrances
- With direct visibility along the path segments of the MIP that connect the building's entrances (the length of key path of the MIP visible from the stair isovist)
- With direct visibility of stair from the junction points of paths of the MIP that link the patterns of movement within the building to the stair (the divergence of the configuration of the MIP from the stair)

In the single stair strategy, only one stair has distinguishable and superior properties relative to the key spatial variables and a concentrated key spatial structure.   The key spatial structures in these buildings have a single entrance or multiple entrances that converge within major organizing spaces such as a lobby or atrium (where there is a convergence of segments of the MIP). In the multiple stair strategy, stairs have distinguishable and superior (although not necessarily equal) properties relative to the key spatial variables and an elongated key spatial structure. The key spatial structure in these building is comprised on major paths (that form part of the MIP) in the building that link distant points of entry (where no one stair is closest to all entrances).

CHAPTER 8:
SUMMARY AND IMPLICATIONS

8.1 Summary

The objective of this research study was to identify the physical environmental features of stairs and buildings associated with voluntary stair use in workplace buildings. This objective was motivated by the potential for stair use to provide a means for increasing and maintaining health through physical activity within a generally sedentary workforce. Previous research on stair use had generally focused on the local features of individual stair environments in an effort to understand stair use as an activity subject to local decision-making. This study approached stair use as an ancillary activity of purposeful travel through buildings. This perspective resulted in the examination of the relationship between stair use and a wide range of physical environmental features of stairs, elevators and buildings.

This thesis utilized a multiple stage approach, to identify, test and cross-validate the association between stair use and a small number of key variables of the built physical environment.

Stage One utilized a review of literature from health promotion, environmental cognition, architectural design and history, to develop a social ecological framework for the identification of the possible physical environmental features of voluntary stair use (Figure 3.1). The physical environmental features were categorized within five themes: Appeal, Comfort, Convenience, Legibility and Safety; and within three levels of spatial decision-making, with the intention of addressing users with a wide range of experience within their buildings. Building users with limited spatial experience and knowledge of a building would mostly use local (the stair environment) to relational (the relationship between a stair and its adjacent environment) features for decision-making during travel across floor levels (Zimring, Haq, 2003). Building users with extensive spatial experience and knowledge of a building would rely principally on relational to global (the relationship of each space in the building to each other) features for decision making during travel across floors. These travelers are also subject to local features when situationally presented with more than one available choices of travel (stair and elevator available at the same moment).

In Stage Two, an empirical study of building users (with generally extensive spatial knowledge of their building) revealed that while each of the five themes of the framework play a role in choice of travel for both same and multiple level travel, there was a substantially greater number of users that identified reasons associated with convenience and legibility of route than for other themes. Survey results indicated that the order of importance to travelers of the five themes of the framework was similar for both same and multiple level travel. Over 90% of buildings users (for both same level and multiple level travel) identified reasons associated with the convenience. Reasons associated with legibility were identified by 48% of building users for their choice of routes which involved travel on stairs. Reasons associated with appeal (22%), comfort (12%) and safety (8.5%) were cited less frequently.

Stage Three of the study developed definitions and measures that operationalized stair use and constructs of the thematic framework (Convenience, Legibility, Appeal, Comfort and Safety). The study identified measures for 20 variables of the physical environment that would be used in a cross-sectional study of stair use in ten 3 to 4-story academic program buildings.

Three statistical analyses were conducted in the Stage Four study of stair use in ten academic buildings. A variability analysis of the twenty physical environmental variables within the ten buildings revealed wide variability in data amongst 17 of the 20 variables. A bivariate regression analysis used to test the research hypotheses concerning the relationships between stair use and the seventeen variables. This results of this analysis indicated that ten variables had a significant relationship with stair use in the buildings. Nine of the ten variables operationalized the constructs of convenience and legibility. Eight of these variables, and stair width which operationalized the social operational comfort were spatial measures of buildings. The analysis indicated some degree of colinearity among the variables which warranted additional consideration. The results infer that stair use is principally influenced by the placement of stairs rather than the appearance of stairs. Multivariate regression analysis indicated that three variables (effective area of each stair, area of stair isovist, and number of turns required between the stair and the most integrated path) explained 53% of stair use in the ten buildings.

Stage Five utilized a case study approach to examine stair use in relation to the graphic representation of the key spatial measures of stair use in each building. The graphic analysis indicated that buildings with high overall levels of stair use optimized the key spatial variables in respect to the location of stair(s) within the building floor plan. The study identified two sets of strategies from buildings with high stair use (over 60% vertical circulation in the building by stairs): high stair use predominately from one well-used stair in the building, and high stair use from the use of several stairs in the building. The graphic analysis identified that high frequencies of stair use is linked to a spatial logic in the placement of stairs and elevators in relation to a key spatial structure for stair use comprised of the location of stairs, elevators, in relation to the arrangement of most integrated paths and the principal points of entry into the building.

8.2 Strategies for the Design of Workplaces to encourage High Stair Use

This outcomes of this study provided evidence for several principles and examples for design strategies for design of buildings which encourage high stair use. This study found that stair use is closely associated with the variables of the buildings that make the stairs convenient and legible along the paths most likely to be traveled. These paths are related to four factors: the distribution of the building’s population, location of the best-used entrances to the building, location of elevators, and global structure of movement between the configuration of spaces within the building (the most integrated paths of movement. The findings of this study suggest that the following strategy may promote stair use in workplace buildings:

> Provide a clear and uncompromising placement of stairs to optimize the measures of key spatial variables of stair use over other modes of vertical travel (the elevator or

other stairs) that are not encouraged or intended for frequent use. These key spatial variables of stair use are:

- Travel distance from stair to nearest entrance
- Travel distance from stair to elevator
- Percentage of total building area served by a stair
- Percentage of total occupant load served by a stair
- Physical accessibility between stair and adjacent spaces
- Area of stair isovist
- Number of turns from closest entrance
- Number of turns from stair to most integrated path
- Stair width

Determine the location of stairs by focusing on the spatial logic that links the placement of stairs, elevators, main points of entry to the building and the building's most integrated paths. The study identified an organizing spatial structure comprised of these elements evident in the individual stairs or collection of stairs, which produced high overall stair use in buildings.

These findings form the foundation of two strategies for the design of buildings which encourage high stair use either from the use of one stair or from several stairs. In addition, the study provided several lessons that indicate that ambiguity and compromise within the spatial logic of location of stairs and elevators in respect to the key building variables may result in lower individual and overall stair performance in buildings.

8.3 Research Study Strengths and Limitations

The validity of this foundational study on stair use within buildings is supported by several factors. This study utilized multiple methods to examine and cross-validate the findings of the cross-sectional study on stair use in buildings. The use of different methods allowed the issues exposed in one study to be examined using other methods. For example, the colinearity amongst variables in the statistical study prompted the investigation and detection of the spatial structure for stair use in the graphic analysis of the key spatial variables.

The sample of ten academic program buildings provided a domain that had several attributes that enhanced the robustness and validity of the study. There was considerable variability in the measures of the physical environmental variables, frequencies of building level stair use and individual stair use with the ten buildings. Academic program buildings possessed similar attributes amongst their buildings population, and organizational structure, which allowed for the control of personal and social organization variables within the study.

The measures of operationalized variables used reliable equipment and methods of measure such metric and area dimensions extracted from digital drawing files of the building's architectural floor plans. The measures for stair and elevator use were validated through pretest trials and equipment had high levels of accuracy and interater reliability.

There are several limitations that warrant consideration in this study and further research. The empirical studies employed two approaches in its investigation of the environmental features that explained stair use in 3 to 4 story workplace buildings. The first approach used a cognitive approach to identify and weigh the influence of the physical environmental factors and features of buildings that influenced route choice. The question asked of each survey participant was aimed at understanding the determinants of their actions. While this method provided a clear indication that stair use was influenced by their convenience and legibility along the routes that people travel through buildings, it did not provide a clear inventory of the building features that supported this decision-making. The next study shifted away from the investigation the cognition of building users and instead focused on their behavior as a means of identifying the building features associated with stair use. The cross-sectional study of ten buildings identified the building features associated with patterns of natural stair use. The study did not purport to establish a casual link between these features and the choice of stairs for vertical travel. In the next step, the graphic analysis addressed the question of how the eight spatial variables explained the patterns of stair use in each building individually. In its entirety, the study relies on inference to make its case that the eight spatial variables and the spatial structure of stair use identified in the study explains why people used the stairs in these buildings. Although it is not possible to provide a definitive causal argument for these features on the basis on this study alone, this study provides the foundation for that quest.

While this study examines the proportion of overall vertical travel that was by stairs, several aspects of the design does not allow direct translation to energy expenditures or health benefits. Because the monitoring was based on beam interruption on the most used stair, it is not possible to determine the length of the trips, whether it was up or down or how widely it was distributed among the users. Its also did not measure stair use between upper floors. The study did not link the number of vertical trips or the number of flights taken to personal attributes (age, gender, fitness level) of the stair users. The principal focus of the study was to identify the physical environment factors that predict stair use in buildings.

The study did not take into account issues that the organizational program of each academic department might impose on stair use. Academic buildings were chosen because they required building occupants to travel several times a day but the study did not measure how these programs may have affected the frequency and patterns of movement between destinations. The issues related to building program was limited to the following: 1) the distribution variable, percentage of occupant load served by stair, addressed how people where distributed in the building relative to program, 2) the graphic analysis identified the potential influence of high occupancy spaces such as lecture rooms on stair use, 3) the distinction of the principal entrances to the building from all other possible points of entry. A study of the role that organizational programs may have on multi-level occupant movement and stair use would add to our greater knowledge.

In addition to the above, this study did not investigate possible variability within the personal and social organizational factors amongst the ten academic buildings that may have affected stair use. No data was collected on the personal attributes of the building's occupants. The measures for stair use were based on the most used fight. In most cases, this was the flight from the ground floor to the floor above. The study did not address the frequency of internal movement by stair between other floors of the buildings.

Another issue relates to the statistical analysis conducted in Chapter 6. This study examined the relationship between the built environment and the frequency of use of thirty-eight stairs and twelve elevators in ten academic buildings. The small number of buildings in the sample precluded the use of a preferred method of statistical analysis for clustered data, hierarchical multivariate regression. Instead the study relied on simple regression analysis to identify the relationships between variables. While it may be possible to revisit statistical analysis as a method to determine a mathematical model for stair use, it is apparent the number of key variables and clustered data would require a larger data set. To address these limitations, this study utilized multiple research methods including a review of available literature from various disciplines, statistical analysis of self-report survey information and measurements of environment and stair and elevator use, and the graphic analysis of case studies, to cross-validate the findings. There is a consistency in the findings of the four investigations that stair use is associated with specific spatial variables that operationalize the convenience and legibility of a stair(s).

An important issue in this study is its generalizability across other workplace domains and populations. Academic program buildings provided a domain that had several attributes that enhanced the robustness of the variability of dependent and independent variables and the control of personal and social organization variables within the study. The findings of the multiple studies affirm the importance that spatial variables of convenience and legibility in stair use during purposeful travel in this generally youthful and healthy population. These findings may have some limitations in their direct application to other workplace domains that possess populations with a greater range of personal attributes such as age, attitudes and behaviors, and health issues and/or workplace organizations that provide more limited opportunities for travel within buildings during the workday. It is hypothesized, that in such populations, the factors of appeal, comfort and safety, which could not be affirmed as statistically associated with stair use in academic buildings, could have a more influential role in stair use in workplaces with older, less active populations.

Another issue pertains to measurement protocols of several of the variables of the study. Many of the measurements of the variables were straightforward and utilized reliable equipment and methods of measure such metric and area dimensions extracted from digital drawing files of the building's architectural floor plans. Other measurement methods such as stair and elevator use were validated through pretest trials. The study however also included several indices that were created for this study to measure complex and qualitative constructs. Although they were based on sound theoretical constructs, they warrant further consideration of their on their construct validity and interater reliability.

The results of the graphic analysis indicate that refinements could be made to the measures of key spatial variables. For example, the area of stair isovist was used to measure visibility in this study although it is apparent from the graphic analysis that other attributes of isovists such as shape and direction are also relevant. Both the statistical and graphic analysis support the development of composite measures for stair use derived from multiple variables (which may address issues of variable colinearity) such as the number or length of line segments of the MIP located within a stair isovist.

8.4 Implications for Design

The results of this study provide persuasive evidence that stair use is related to the placement of stairs within a building. While these findings need to be replicated, they can be formulated into a set of design recommendations for the placement of stairs in buildings, where stair use is encouraged.

Based on this study, the follow basic design recommendations can be made:

- Locate stairs directly along the main paths of circulation, at or linking the principal entrance(s) to the building. Locate stairs between the entrance and the elevator such that the stairs are closer and initially more visible than the elevator from the entrance.
- Locate stairs so that their point of entry (door or first step) is visible from the elevator
- Locate stairs so they are in close proximity and highly visible to where people are located with in the building. Locate stairs between the spaces where people work, congregate and/or travel and the elevator.
- Orient the stair so it is visible from the largest area where people travel. Locate stairs so it is more visible than the elevator from the main entry and from multiple directions of travel along the main paths of circulation in the building.
- Orient the entrance doors to the stair and/or the first step of an open stair so that it requires the fewest turns in direction to enter the stair from the entrance and the main paths of circulation in the building.

- Provide sufficient stair width to accommodate people traveling by stairs in groups for the multiple types of activities that occur in the building including social engagement, high occupancy movement and emergency exiting.
- When possible maintain accessibility between floors at all levels Locate stairs within the public area of the building.
- Increase the visibility of a stair by providing open stairs such as grand stairs, open non-grand stairs between floors (when an interconnected floor space is permitted by code), electronic hold-open devices on doors of enclosed stairs, and/or fire-rated glass partitions (when a fire separation is required by code).

8.5 Implications for Future Research

The foundation for stair research provided in this study offers a variety of opportunities for future research. Eight areas of future research are identified.

1) **Understand the impact on public health**

Several questions present themselves in making this link. How much physical activity is achieved by using stairs regularly in a workplace? What percentage of office workplace physical activity is the result of stair use? Does stair use encourage other types of physical activity? Are people more active in buildings that encourage stair use through the environmental design? How is this generalized across other physical activity opportunities?

2) **Understand the role of building**

How does the way that the programmed activities and spaces are arranged in a building affect the opportunities for multi-level travel? Can more travel (that includes stair use) be created by way that spaces and work practices are arranged within buildings? How does building program affect the opportunities for internal movement (other than the ground to next floor) in the building? While stair use has been identified as the key opportunity for physical activity in the building, what is the role of other designed elements such as exercise rooms and walking paths that may link with stairs in encouraging physical activity?

3) **Refine spatial measures**

The graphic analysis indicated stair use is associated with the presence and composition of spatial structures, which combine features such as the area of isovist, and segments of the most integrated paths. Future research should focus on the development of composite measures for stair use that incorporate metric and space syntax techniques in the development of assessment tools for existing building and new building design

4) **Establish causal links**

Another direction for research is the development of a causal link between the spatial variables and stair use. While the case study analysis identified an association between stair use and the presence of key spatial variables within a spatial structure, the relative influence of each spatial variable on stair use was not clear. It would be helpful to understand how this spatial logic of stair use is structured in relation to each variable or composite variables. This would provide a means to understand under what circumstances these variables either mediate or moderate stair use. Greater capability to decipher or construct this logic within the design of buildings would lead to other areas of both research and application. This study provides a foundation for this research which may use a variety of methods to explore this issue. One method may include exploring how people understand the spatial and other attributes of a building in regards to stair use by asking building occupants to draw cognitive maps of their building for all options of travel. Another method could use intervention studies in real life or virtual domains to explore the influence of the specific variables on stair use.

5) **Identify spatial typologies**

The recognition of spatial typologies would be useful in developing best practices for building design. Typological studies of common building types may also offer an opportunity to determine with increased precision the relative influence of spatial variables. A study of buildings with common attributes could also allow for investigation of the influence of variances in single variables or measures through intervention studies, a method generally difficult to achieve due to variability within building designs.

6) **Generalize to other workplaces**

Public and corporate office workplaces provides the greatest opportunity for the application of research findings into practice as this domain address the working population most at risk from sedentary lifestyle choices. The largest employers of office workers are federal and state governments. These agencies that have a historic record of support for applied research and the early diffusion of the findings of evidence-based research into their environmental and operational practices including building design and best practice guidelines.

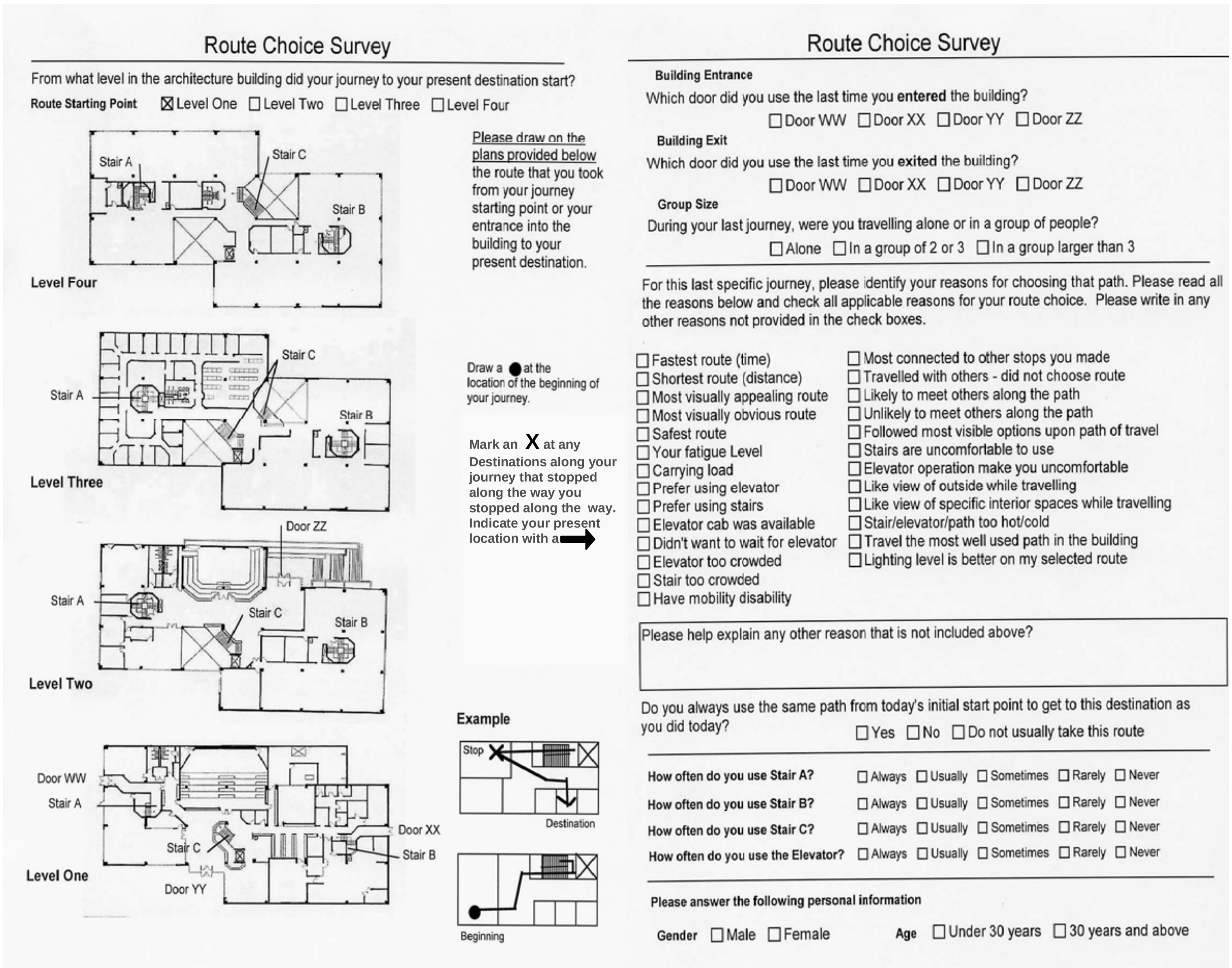
7) **Understand the role of elevator placement**

There has been limited convergence to date between stair research and the parallel field of elevator research. A comprehensive investigation of the relationship between these modes would have an important role in furthering our comprehension of multiple level travel in buildings.

8) Link research to practice

Additional research is needed on the relationship between the variables that influence stair use and building practices in two specific areas. One area of practice is building code regulations. There is a need to reevaluate the current logic and standards that govern emergency evacuation from high-rise and high occupancy buildings. This re-evaluation should include a review of the minimum requirements for the width, placement and separation of stair for emergency exiting (Pauls, 2002). It should also consider the possible contribution to occupant safety that may result from improving the placement (convenience, intelligibility, and visibility) of stairs to encourage every day travel. Building occupants who have a familiarity with their options for egress from everyday use of stairs may be better prepared for emergency evacuations. A second area of study should focus on the economic influences and implications of buildings designed to encourage stair use. While the key finding of this study suggest that possible low cost refinements in the visible and convenient placement of stair rather than the articulation of stairs governs stair use, the relative economic costs and benefits have yet to be determined and evaluated.

APPENDIX A:
SUPPORTING DATA AND ANALYSIS



Route Choice Survey

From what level in the architecture building did your journey to your present destination start?

Route Starting Point ☒ Level One ☐ Level Two ☐ Level Three ☐ Level Four

Please draw on the plans provided below the route that you took from your journey starting point or your entrance into the building to your present destination.

Draw a ● at the location of the beginning of your journey.

Mark an **X** at any Destinations along your journey that stopped along the way you stopped along the way. Indicate your present location with a ➡

Example

Route Choice Survey

Building Entrance

Which door did you use the last time you **entered** the building?

☐ Door WW ☐ Door XX ☐ Door YY ☐ Door ZZ

Building Exit

Which door did you use the last time you **exited** the building?

☐ Door WW ☐ Door XX ☐ Door YY ☐ Door ZZ

Group Size

During your last journey, were you travelling alone or in a group of people?

☐ Alone ☐ In a group of 2 or 3 ☐ In a group larger than 3

For this last specific journey, please identify your reasons for choosing that path. Please read all the reasons below and check all applicable reasons for your route choice. Please write in any other reasons not provided in the check boxes.

☐ Fastest route (time)
☐ Shortest route (distance)
☐ Most visually appealing route
☐ Most visually obvious route
☐ Safest route
☐ Your fatigue Level
☐ Carrying load
☐ Prefer using elevator
☐ Prefer using stairs
☐ Elevator cab was available
☐ Didn't want to wait for elevator
☐ Elevator too crowded
☐ Stair too crowded
☐ Have mobility disability
☐ Most connected to other stops you made
☐ Travelled with others - did not choose route
☐ Likely to meet others along the path
☐ Unlikely to meet others along the path
☐ Followed most visible options upon path of travel
☐ Stairs are uncomfortable to use
☐ Elevator operation make you uncomfortable
☐ Like view of outside while travelling
☐ Like view of specific interior spaces while travelling
☐ Stair/elevator/path too hot/cold
☐ Travel the most well used path in the building
☐ Lighting level is better on my selected route

Please help explain any other reason that is not included above?

Do you always use the same path from today's initial start point to get to this destination as you did today?

☐ Yes ☐ No ☐ Do not usually take this route

How often do you use Stair A?	☐ Always	☐ Usually	☐ Sometimes	☐ Rarely	☐ Never
How often do you use Stair B?	☐ Always	☐ Usually	☐ Sometimes	☐ Rarely	☐ Never
How often do you use Stair C?	☐ Always	☐ Usually	☐ Sometimes	☐ Rarely	☐ Never
How often do you use the Elevator?	☐ Always	☐ Usually	☐ Sometimes	☐ Rarely	☐ Never

Please answer the following personal information

Gender ☐ Male ☐ Female **Age** ☐ Under 30 years ☐ 30 years and above

Figure A.1 Copy of Building User Reasons for Route Choice Survey

Table A.1 Measurements of Stair and Elevator Use in the Sample of Ten Academic Buildings

GTCOA	Stair GTCOA A	Stair GTCOA B	Stair GTCOA C	Stair GTCOA D	Stair GTCOA E	Stair GTCOA F	Elevator GTCOA ELV		Bldg Total Vertical Circulation	Bldg Total Stair Use
Stair Use										
Monday	1015	309	128	421	478	10	372			
Tuesday	966	311	133	510	565	6	354			
Wednesday	1134	456	127	503	577	14	312			
Thursday	865	310	122	525	577	17	416			
Friday	740	310	101	536	518	2	385			
Total	4720	1696	611	2495	2715	49	1839		14267	12428
Average	944.00	339.20	122.20	499.00	543.00	9.80	367.80		2853.4	2485.6
% of total bldg stair use	38.0%	13.6%	4.9%	20.1%	21.8%	0.4%			% Elevator Use	% Stair Use
% of total bldg Vertical Circulation	33.1%	11.9%	4.3%	17.5%	19.0%	0.3%	12.9%		12.9%	87.1%
GTEL	Stair GTEL A	Stair GTEL B	Stair GTEL C	Stair GTEL D	Stair GTEL E	Elevator GTEL ELV			Bldg Total Vertical Circulation	Bldg Total Stair Use
Stair Use										
Monday	368	269	129	682	342	220				
Tuesday	314	222	105	642	305	168				
Wednesday	347	254	125	769	290	259				
Thursday	419	178	89	682	281	287				
Friday	393	231	112	694	305	284				
Total	1841	1154	560	3469	1523	1218			9765	8547
Average	368.2	230.8	112	693.8	304.6	243.6			1953	1709.4
% of total bldg stair use	21.5%	13.5%	6.6%	40.6%	17.8%				% Elevator Use	% Stair Use
% of total bldg Vertical Circulation	18.9%	11.8%	5.7%	35.5%	15.6%	12.5%			12.5%	87.5%
GTUAW	Stair GTUAW A	Stair GTUAW B	Stair GTUAW C	Elevator GTUAW ELV					Bldg Total Vertical Circulation	Bldg Total Stair Use
Stair Use										
Monday	448	133	31	*						
Tuesday	473	114	23	*						
Wednesday	467	140	28	*						
Thursday	555	128	26	*						
Friday	383	124	23	*						
Total	2326	639	131	*874*					3970	3096
Average	465.2	127.8	26.2	174.8					992.5	206.4
% of total bldg stair use	75.1%	20.6%	4.2%						% Elevator Use	% Stair Use
% of total bldg Vertical Circulation	58.6%	16.1%	3.3%	22.0%					22.0%	78.0%

Table A.1 (continued)

GTIBB	Stair GTIBB A	Stair GTIBB B	Stair GTIBB C	Stair GTIBB D	Stair GTIBB E	Stair GTIBB F	Elevator GTIBB ELV1	Elevator GTIBB ELV2	Bldg Total Vertical Circulation	Bldg Total Stair Use
Stair Use										
Monday	696	30	162	56	59	67	373	582		
Tuesday	551	23	180	97	46	68	475	455		
Wednesday	696	20	192	95	44	75	487	633		
Thursday	778	18	174	118	60	68	572	621		
Friday	704	21	181	94	62	57	287	465		
Total	3425	112	889	460	271	335	2194	2756	10442	5492
Average	685	22.4	177.8	92	54.2	67	438.8	551.2	1305.3	183.1
% of total bldg stair use	62.4%	2.0%	16.2%	8.4%	4.9%	6.1%			% Elevator Use	% Stair Use
% of total bldg Vertical Circulation	32.8%	1.1%	8.5%	4.4%	2.6%	3.2%	21.0%	26.4%	47.4%	52.6%
GTMARC	Stair GTMARC A	Stair GTMARC B	Stair GTMARC C	Stair GTMARC D	Stair GTMARC E	Elevator GTMARC ELV			Bldg Total Vertical Circulation	Bldg Total Stair Use
Stair Use										
Monday	616	58	47	53	81	496				
Tuesday	665	32	46	52	87	320				
Wednesday	613	58	68	57	80	420				
Thursday	544	42	28	58	87	411				
Friday	449	70	37	31	72	385				
Total	2887	260	226	251	407	2032			6063	4031
Average	577.4	52	45.2	50.2	81.4	406.4			202.1	161.24
% of total bldg stair use	71.6%	6.5%	5.6%	6.2%	10.1%				% Elevator Use	% Stair Use
% of total bldg Vertical Circulation	47.6%	4.3%	3.7%	4.1%	6.7%	33.5%			33.51%	66.49%
RYARSC	Stair RYARSC A	Stair RYARSC B	Stair RYARSC C	Elevator RYARSC ELV					Bldg Total Vertical Circulation	Bldg Total Stair Use
Stair Use										
Monday	1203	83	0	*						
Tuesday	1041	72	25	*						
Wednesday	1115	55	41	*						
Thursday	957	65	55	*						
Friday	637	47	41	*						
Total	4953	322	162	*948*					6385	5437
Average	990.6	64.4	32.4	189.6					319.3	362.5
% of total bldg stair use	91.1%	5.9%	3.0%						% Elevator Use	% Stair Use
% of total bldg Vertical Circulation	77.6%	5.0%	2.5%	14.8%					14.8%	85.2%

Table A.1 (continued)

RYGCM	Stair RYGCM A	Stair RYGCM B	Elevator RYGCM ELV						Bldg Total Vertical Circulation	Bldg Total Stair Use
Stair Use										
Monday	1103	131	490							
Tuesday	894	124	331							
Wednesday	797	113	290							
Thursday	816	113	275							
Friday	526	69	231							
Total	4136	550	1617						6303	4686
Average	526	110	323.4						319.8	318
% of total bldg stair use	88.3%	11.7%							% Elevator Use	% Stair Use
% of total bldg Vertical Circulation	65.6%	8.7%	25.7%						25.7%	74.3%
RYINT	Stair RYINT A	Stair RYINT B	Elevator RYINT ELV						Bldg Total Vertical Circulation	Bldg Total Stair Use
Stair Use										
Monday	529	250	365							
Tuesday	548	237	320							
Wednesday	739	267	327							
Thursday	636	267	240							
Friday	217	141	175							
Total	2669	1162	1427						5258	3831
Average	533.8	232.4	285.4						350.5	383.1
% of total bldg stair use	69.7%	30.3%							% Elevator Use	% Stair Use
% of total bldg Vertical Circulation	50.8%	22.1%	27.1%						27.1%	72.9%
RYMON	Stair RYMON A	Stair RYMON B	Elevator RYMON ELV						Bldg Total Vertical Circulation	Bldg Total Stair Use
Stair Use										
Monday	154	77	385							
Tuesday	243	92	454							
Wednesday	124	73	376							
Thursday	199	83	369							
Friday	65	47	162							
Total	785	372	1746						2903	1157
Average	157	74.4	349.2						193.5	115.7
% of total bldg stair use	67.8%	32.2%							% Elevator Use	% Stair Use
% of total bldg Vertical Circulation	27.0%	12.8%	60.1%						60.1%	39.9%

Table A.1 (continued)

RYENG	Stair RYENG A	Stair RYENG B	Stair RYENG C	Stair RYENG D	Elevator RYENG ELV1	Elevator RYENG ELV2			Bldg Total Vertical Circulation	Bldg Total Stair Use
Stair Use										
Monday	1194	659	58	65	694	604				
Tuesday	1086	616	43	63	930	356				
Wednesday	1208	569	40	57	608	597				
Thursday	1273	759	39	49	610	606				
Friday										
Total	4761	2603	180	234	2842	2163			12783	7778
Average	1190.3	650.8	45.0	56.3	716.0	519.7			531.7	2514.7
% of total bldg stair use	61.2%	33.5%	2.3%	3.0%					% Elevator Use	% Stair Use
% of total bldg Vertical Circulation	37.2%	20.3%	1.3%	1.2%	23%	17.0%			40.0%	60.0%
									Study Total Vertical Circulation	Study Total Stair Use
									78139	56483
									% Elevator Use	% Stair Use
									28%	72.3%

* Values in Italics were determined from visual observation during a shorter time span and have been prorated to represent elevator use over an 8 hour time frame

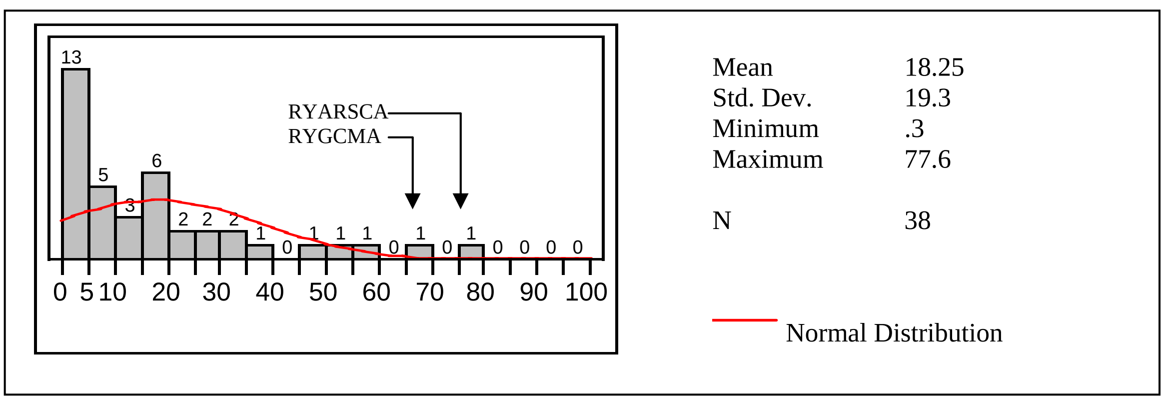


Figure A.2 **Distribution of Individual Stair's Use as a Percent of Vertical Circulation in their Building**

A. 3 Normalizing the Data Set

Statistical procedures such as linear regression are based on some basic assumptions including that the data is distributed normally. In this data set, the dependent variable, Stair Use (the percentage of trip attributed to a stair in relation to all vertical trips recorded within a building), is positively skewed, which indicates that there is a tendency for many of the stairs within the 10 buildings to have low levels of use while the higher percentage scores for stairs use in the data set are more spread out. In order to utilize regression analysis procedures to examine the relationships between the dependent variable, stair use, and the variety of independent physical environmental variables, the data was transformed using a normalizing transformation procedure (Kohout 1974).

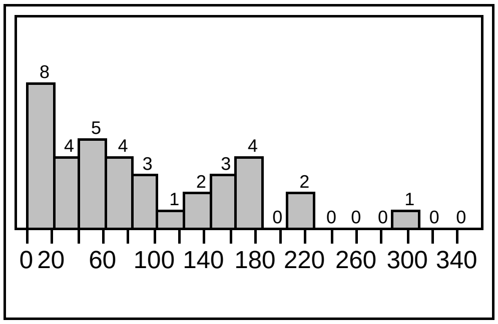
1) Stair use that is represented as a raw percentage score is sorted to construct a cumulative frequency distribution.
2) The cumulative frequencies are transformed into cumulative proportion by dividing the cumulative frequencies by N, the number of scores (38)
3) Using a standard normal distribution table, the z-scores for each cumulative proportion are recorded a normalized z-scores
4) The normalized z-scores are converted to normalized raw scores (which restores the unit of measurement, in this case %), by multiplying the normalized z-score by the mean (in this case 17.8, Figure 6.2) and adding the standard deviation (19.3, Figure 6.2), then converting the new scores through addition or subtract so that the new normalized raw scores have a mean of zero.

Table A.2 Normalizing Transformation of Individual Stair's Use as a Percent of Vertical Circulation in their Building

Stair Name	Stair Use	Cumulative Frequency	Cumulative Proportion	Normalized Proportion	Normalized z-Scores	Normalized Raw Score
GTCOAF	0.3	1	0.03	0.47	-1.94	-41.331358
GTIBBB	1.1	2	0.05	0.45	-1.62	-35.182558
RYENGC	1.4	3	0.08	0.42	-1.41	-31.083358
RYENGD	1.8	4	0.11	0.39	-1.25	-27.960158
RYARSCC	2.5	5	0.13	0.37	-1.12	-25.422558
GTIBBE	2.6	6	0.16	0.34	-1.05	-24.056158
GTIBBF	3.2	7	0.18	0.32	-0.9	-21.128158
GTUAWC	3.3	8	0.21	0.29	-0.81	-19.273758
GTMARCC	3.7	9	0.24	0.26	-0.72	-17.516958
GTMARCD	4.1	10	0.26	0.24	-0.64	-15.955358
GTCOAC	4.3	11	0.29	0.21	-0.56	-14.393758
GTMARCB	4.3	12	0.32	0.18	-0.48	-12.929758
GTIBBD	4.4	13	0.34	0.16	-0.41	-11.465758
RYARSCB	5	14	0.37	0.13	-0.34	-10.099358
GTELC	5.7	15	0.39	0.11	-0.26	-8.537758
GTMARCE	6.7	16	0.42	0.08	-0.21	-7.561758
GTIBBC	8.5	17	0.45	0.05	-0.35	-10.392158
RYGCMB	8.7	18	0.47	0.03	-0.05	-4.536158
GTELB	11.8	19	0.50	0.00	0	-3.560158
GTCOAB	11.9	20	0.53	0.03	0.07	-2.291358
RYMONB	12.8	21	0.55	0.05	0.14	-0.924958
GTELE	15.6	22	0.58	0.08	0.21	0.441442
GTUAWB	16.1	23	0.61	0.11	0.27	1.612642
GTCOAD	17.5	24	0.63	0.13	0.35	3.174242
GTELD	17.5	25	0.66	0.16	0.41	4.345442
GTELA	18.9	26	0.68	0.18	0.48	5.809442
GTCOAE	19	27	0.71	0.21	0.56	7.273442
RYENGB	20.4	28	0.74	0.24	0.64	8.835042
RYINTB	22.1	29	0.76	0.26	0.72	10.396642
RYMONA	27	30	0.79	0.29	0.81	12.153442
GTIBBA	32.8	31	0.82	0.32	0.9	14.007842
GTCOAA	33.1	32	0.84	0.34	1.05	16.935842
RYENGA	37.9	33	0.87	0.37	1.12	18.302242
GTMARCA	47.6	34	0.89	0.39	1.25	20.839842
RYINTA	50.8	35	0.92	0.42	1.41	23.963042
GTUAWA	58.6	36	0.95	0.45	1.62	28.062242
RYGCMA	65.6	37	0.97	0.47	1.94	34.308642
RYARSCA	77.6	38	1.00	0.50	5	94.039842

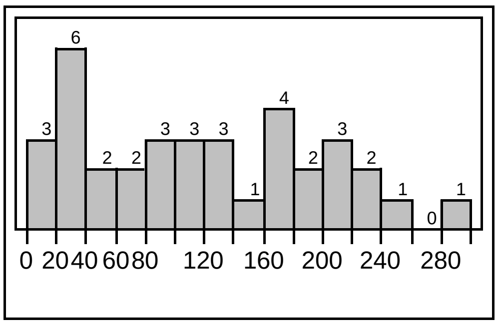
Table A.3 Normalizing Transformation of Building Stair Use as a Percent of Vertical Circulation in their Building

Building Designation	Percentage Stair Use	Frequency Distribution	Cumulative Proportion	Normalized Proportions	Normalized z-Scores	Normalized Raw Scores
RYMON	39.9	1	0.1	-0.4	-1.28	-74.49
GTIBB	52.6	2	0.2	-0.3	-0.84	-43.48
RYENG	60.8	3	0.3	-0.2	-0.525	-21.28
GTMARC	66.5	4	0.4	-0.1	-0.245	-1.55
RYINT	72.9	5	0.5	0	0	15.72
RYGCM	74.3	6	0.6	0.1	0.245	32.99
GTUAW	78	7	0.7	0.2	0.525	52.72
RYARSC	85.2	8	0.8	0.3	0.84	74.92
GTCOA	87.1	9	0.9	0.4	1.28	105.93
GTEL	87.5	10	1	0.5	5	368.12



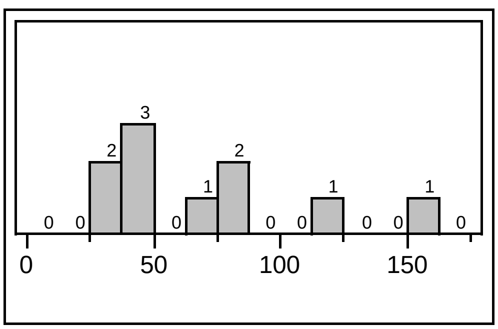
Quantiles			Moments	
100%	Maximum	281.0	Mean	93.82
75%		185.5	Standard Dev.	82.00
50%	Median	106.5	Std Err Mean	13.30
25%		38.0		
0%	Minimum	3.0		

Figure A.3 Descriptive Statistics for Proximity Variables: Distance from Closest Entrance



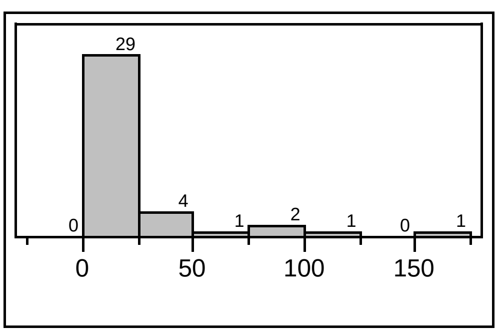
Quantiles			Moments	
100%	Maximum	281	Mean	118.41
75%		185.5	Standard Dev.	78.28
50%	Median	106.5	Std Err Mean	13.05
25%		38.0		
0%	Minimum	6.0		

Figure A.4 Descriptive Statistics for Proximity Variable: Distance between Stair and Elevator



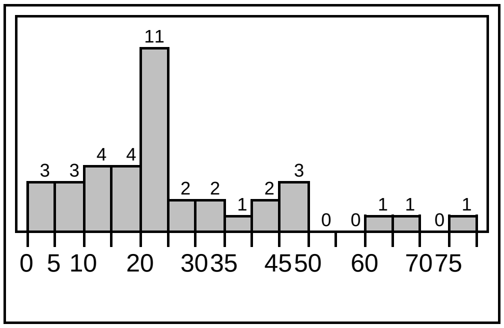
Quantiles			Moments	
100%	Maximum	159	Mean	23.87
75%		22.0	Standard Dev.	34.57
50%	Median	13.0	Std Err Mean	5.61
25%		4.75		
0%	Minimum	0		

Figure A.5 Descriptive Statistics for Proximity Variable: Distance from MIP



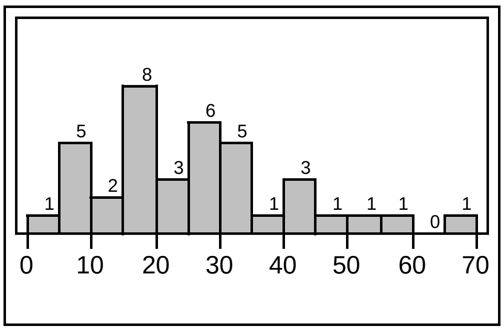
Quantiles			Moments	
100%	Maximum	159	Mean	67.4
75%		91.75	Standard Dev.	43.86
50%	Median	53.5	Std Err Mean	13.87
25%		35.5		
0%	Minimum	25		

Figure A.6 Descriptive Statistics for Proximity Variable: Distance from MIP >25 feet



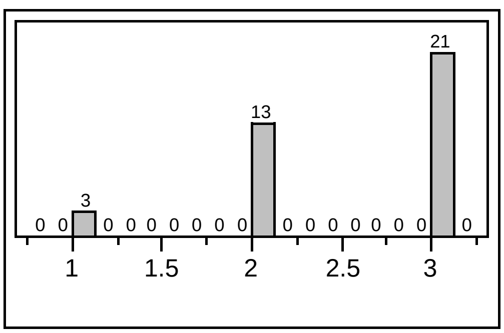
Quantiles			Moments	
100%	Maximum	77.6	Mean	26.14
75%		34.43	Standard Dev.	17.72
50%	Median	22.15	Std Err Mean	2.87
25%		14.63		
0%	Minimum	3.2		

Figure A.7 Descriptive Statistics for Distribution Variable: % of Total Occupant Load



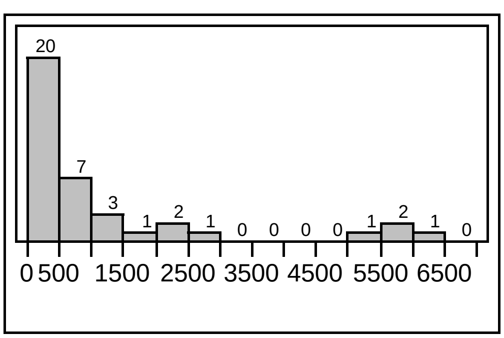
Quantiles			Moments	
100%	Maximum	67.10	Mean	26.20
75%		33.53	Standard Dev.	14.83
50%	Median	23.95	Std Err Mean	2.41
25%		17.55		
0%	Minimum	.40		

Figure A.8 Descriptive Statistics for Distribution Variable: % of Total Building Area



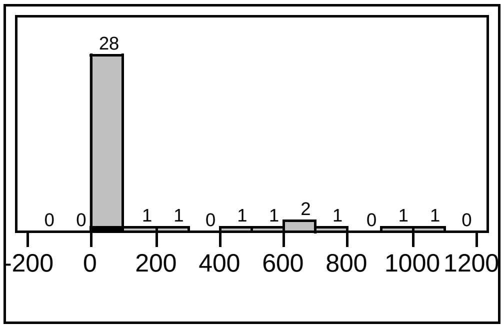
Quantiles			Moments	
100%	Maximum	3.0	Mean	2.49
75%		3.0	Standard Dev.	0.65
50%	Median	3.0	Std Err Mean	0.11
25%		2.0		
0%	Minimum	1.0		

Figure A.9 Descriptive Statistics for Accessibility Variable: Physical Accessibility



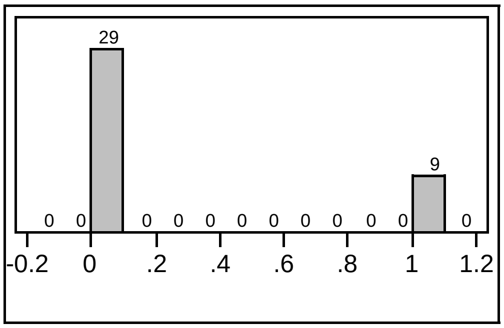
Quantiles			Moments	
100%	Maximum	6156.0	Mean	1167.0
75%		1176.5	Standard Dev.	1680.87
50%	Median	458.0	Std Err Mean	272.67
25%		196.3		
0%	Minimum	59.0		

Figure A.10 Descriptive Statistics for Visibility Variable: Average Area of Stair Isovist



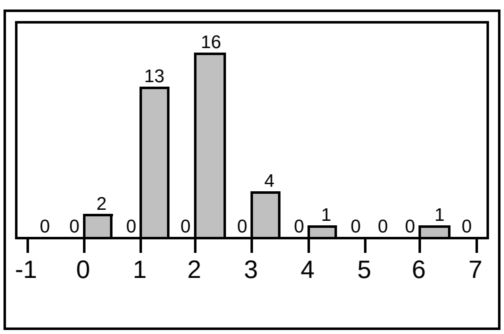
Quantiles			Moments	
100%	Maximum	1053.0	Mean	151.66
75%		104.0	Standard Dev.	296.66
50%	Median	0.91	Std Err Mean	48.77
25%		0.73		
0%	Minimum	0.208		

Figure A.11 Descriptive Statistics for Visibility Variable: Area of Interior Exposure



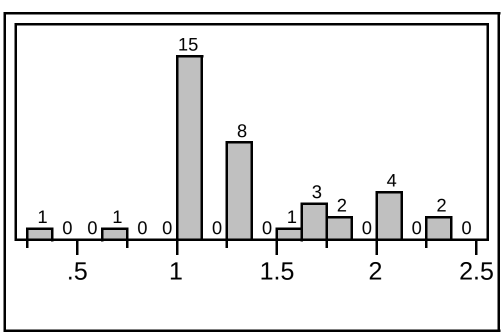
Quantiles			Moments	
100%	Maximum	1.0	Mean	0.237
75%		0.25	Standard Dev.	0.431
50%	Median	0	Std Err Mean	0.070
25%		0		
0%	Minimum	0		

Figure A.12 Descriptive Statistics for Imageability Variable: Stair Types



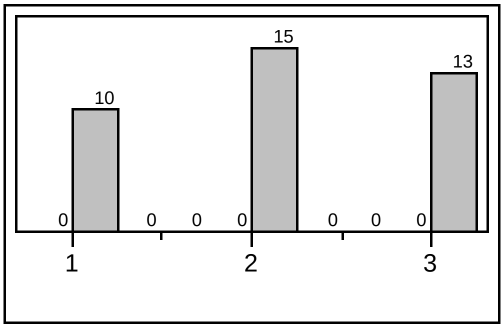
Quantiles			Moments	
100%	Maximum	6	Mean	1.81
75%		2.0	Standard Dev.	1.10
50%	Median	2.0	Std Err Mean	0.18
25%		1.0		
0%	Minimum	0		

Figure A.13 Descriptive Statistics for Intelligibility Variable: Number of Turns from Closest Entrance



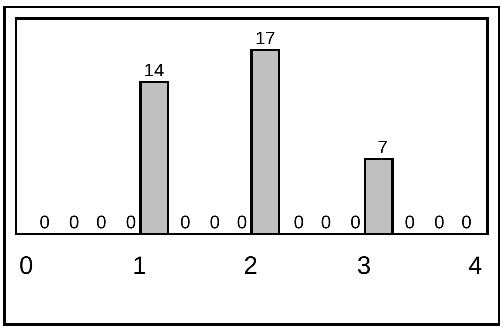
Quantiles			Moments	
100%	Maximum	2.33	Mean	1.33
75%		1.67	Standard Dev.	0.46
50%	Median	1.33	Std Err Mean	0.08
25%		1.0		
0%	Minimum	0.33		

Figure A.14 Descriptive Statistics for Intelligibility Variable: Number of Turns from MIP



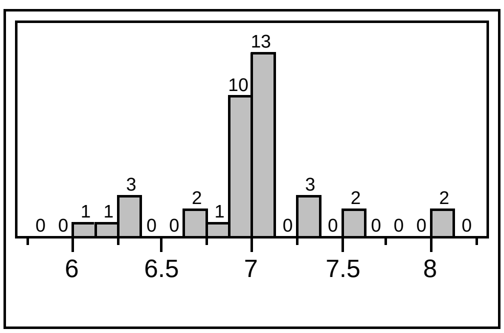
Quantiles			Moments	
100%	Maximum	3.0	Mean	2.11
75%		3.0	Standard Dev.	.77
50%	Median	2.0	Std Err Mean	0.124
25%		1.5		
0%	Minimum	1.0		

Figure A.15 Descriptive Statistics for Appeal Variable: View from Stair



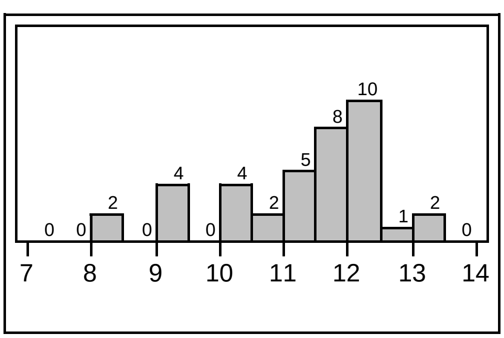
Quantiles			Moments	
100%	Maximum	3	Mean	1.82
75%		2.0	Standard Dev.	0.73
50%	Median	2.0	Std Err Mean	0.12
25%		1.0		
0%	Minimum	1.0		

Figure A.16 Descriptive Statistics for Appeal Variable: Stair Articulation



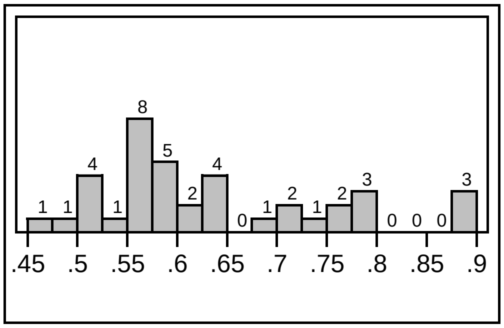
Quantiles			Moments	
100%	Maximum	8.0	Mean	6.93
75%		7.0	Standard Dev.	0.42
50%	Median	7.0	Std Err Mean	0.07
25%		6.88		
0%	Minimum	6.0		

Figure A.17 Descriptive Statistics for Gait Compatibility Variable: Riser Height



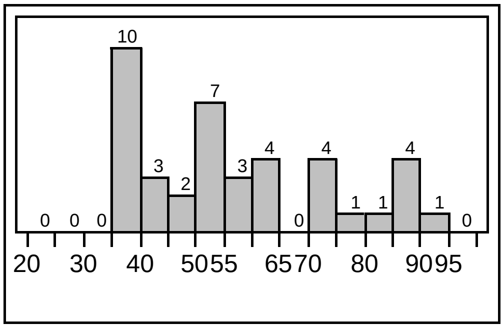
Quantiles			Moments	
100%	Maximum	13.25	Mean	11.12
75%		12.0	Standard Dev.	1.31
50%	Median	11.63	Std Err Mean	0.21
25%		10.25		
0%	Minimum	8.0		

Figure A.18 Descriptive Statistics for Gait Compatibility Variable: Tread Depth



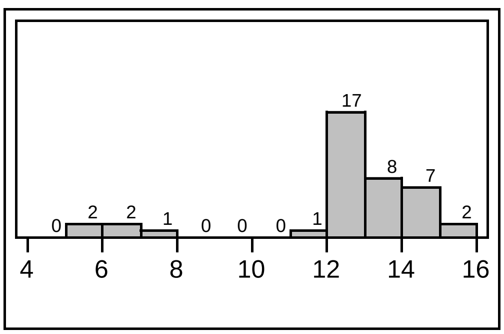
Quantiles			Moments	
100%	Maximum	0.89	Mean	0.63
75%		0.71	Standard Dev.	0.11
50%	Median	0.59	Std Err Mean	0.02
25%		0.56		
0%	Minimum	0.45		

Figure A.19 Descriptive Statistics for Gait Compatibility Variable: Riser/Tread Ratio



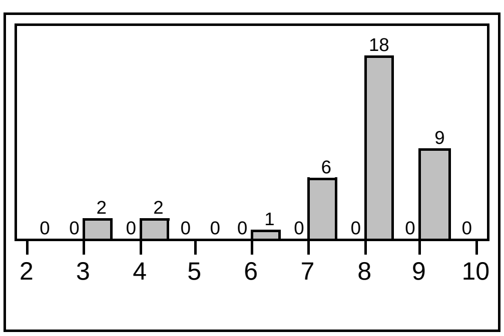
Quantiles			Moments	
100%	Maximum	94.75	Mean	57.24
75%		71.75	Standard Dev.	17.25
50%	Median	54.0	Std Err Mean	2.73
25%		40.06		
0%	Minimum	36.75		

Figure A.20 Descriptive Statistics for Social Operational Comfort Variable: Stair Width



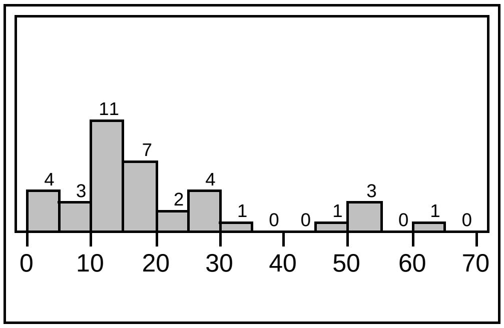
Quantiles			Moments	
100%	Maximum	15.0	Mean	11.9
75%		13.0	Standard Dev.	2.53
50%	Median	12.0	Std Err Mean	0.4
25%		12.0		
0%	Minimum	5.0		

Figure A.21 Descriptive Statistics for Exertion Capability Variable: Maximum Number of Steps between Landings



Quantiles			Moments	
100%	Maximum	9.0	Mean	7.55
75%		8.0	Standard Dev.	1.59
50%	Median	8.0	Std Err Mean	0.26
25%		7.0		
0%	Minimum	3.0		

Figure A.22 Descriptive Statistics for Surveillance Variable: Maintenance Level



Quantiles			Moments	
100%	Maximum	60.0	Mean	19.05
75%		25.0	Standard Dev.	15.29
50%	Median	15.0	Std Err Mean	2.51
25%		10.0		
0%	Minimum	2.0		

Figure A.23 Descriptive Statistics for Safety Variable: Minimum Illumination Level

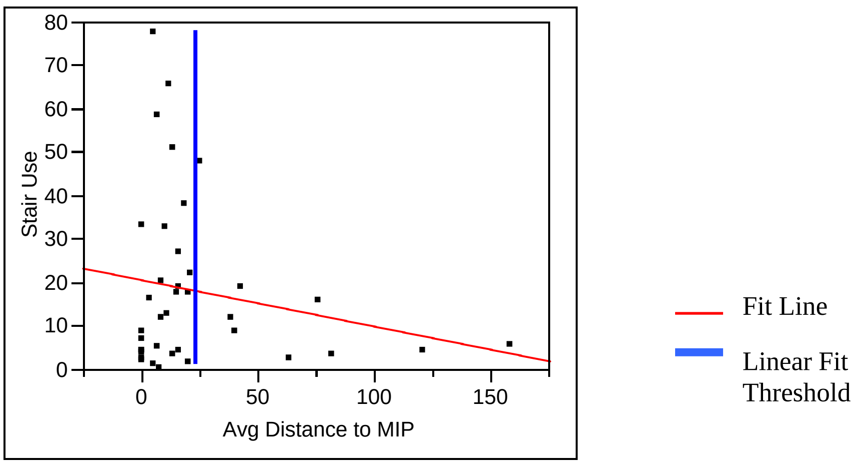
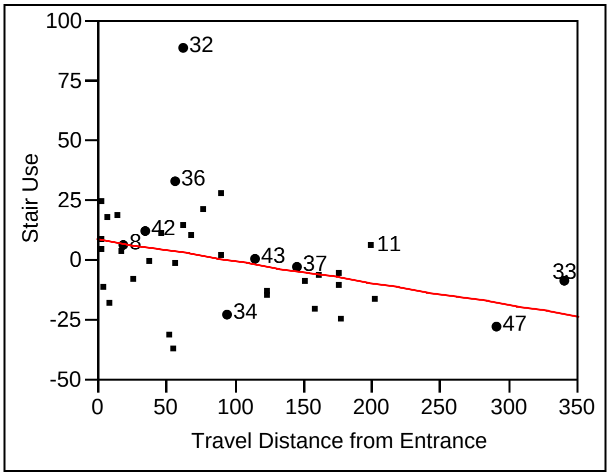


Figure A.24 Graph of Bivariate Analysis of Stair Use and the Distance from Stair to Most Integrated Path



Legend

8	Stair GTELA
11	Stair GTELD
32	Stair RYARSCA
36	Stair RYGCMA
37	Stair RYGCMB
42	Stair RYMONA
43	Stair RYMONB

Linear Fit

Analysis of Variance

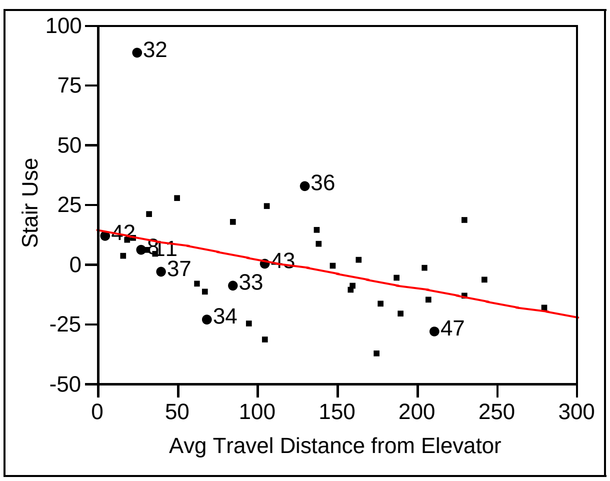
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	2089.088	2089.09	4.5678
Error	36	16464.680	457.35	Prob > F
C. Total	37	18553.768		0.0394

RSquare	0.112596
RSquare Adj	0.087946
Root Mean Square Error	21.38579
Mean of Response	-0.00042
Observations (or Sum Wgts)	38

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	8.5959875	5.311659	1.62	0.1143
Travel Distance from Entrance	-0.091631	0.042873	-2.14	0.0394

Figure A.25 Bivariate Fit of Stair Use By Average Travel Distance from Entrance



Legend

8	Stair GTELA
11	Stair GTELD
32	Stair RYARSCA
36	Stair RYGCMA
37	Stair RYGCMB
42	Stair RYMONA
43	Stair RYMONB

Linear Fit

Analysis of Variance

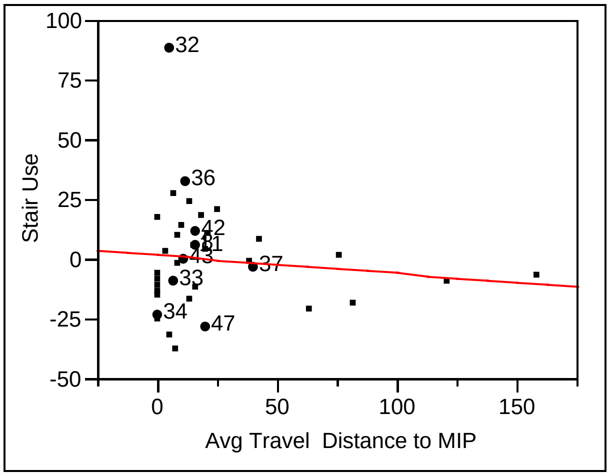
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	3261.236	3261.24	7.6772
Error	36	15292.532	424.79	Prob > F
C. Total	37	18553.768		0.0088

RSquare	0.175772
RSquare Adj	0.152877
Root Mean Square Error	20.6105
Mean of Response	-0.00042
Observations (or Sum Wgts)	38

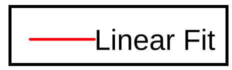
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	14.419655	6.185775	2.33	0.0255
Avg Travel Distance from Elevator	-0.12234	0.044154	-2.77	0.0088

Figure A.26 Bivariate Fit of Stair Use by Average Travel Distance from Elevator



Legend	
8	Stair GTELA
11	Stair GTELD
32	Stair RYARSCA
36	Stair RYGCMA
37	Stair RYGCMB
42	Stair RYMONA
43	Stair RYMONB



Analysis of Variance

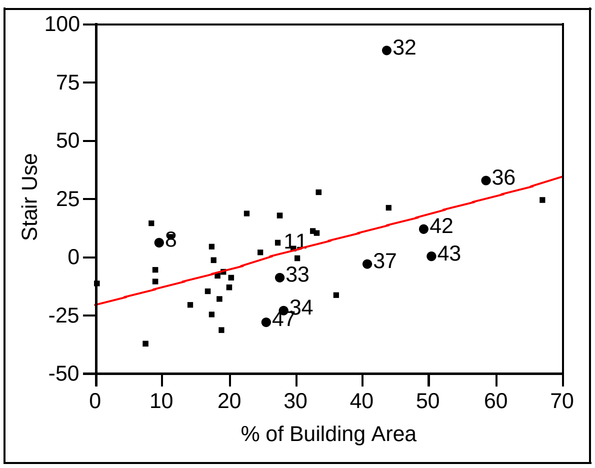
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	250.282	250.282	0.4923
Error	36	18303.485	508.430	Prob > F
C. Total	37	18553.768		0.4874

Parameter Estimates

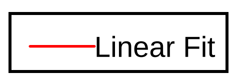
Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1.7955373	4.464532	0.40	0.6899
Avg Travel from Distance to MIP	-0.075244	0.107244	-0.70	0.4874

RSquare	0.01349
RSquare Adj	-0.01391
Root Mean Square Error	22.5484
Mean of Response	-0.00042
Observations (or Sum Wgts)	38

Figure A.27 Bivariate Fit of Stair Use by Average Travel Distance to MIP



Legend	
8	Stair GTELA
11	Stair GTELD
32	Stair RYARSCA
36	Stair RYGCMA
37	Stair RYGCMB
42	Stair RYMONA
43	Stair RYMONB



Analysis of Variance

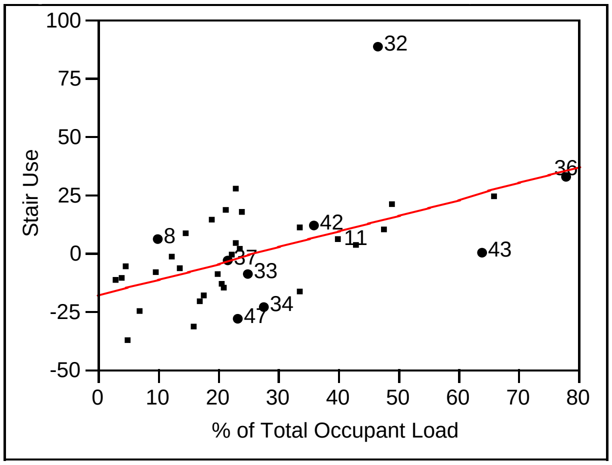
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	4962.006	4962.01	13.1427
Error	36	13591.761	377.55	Prob > F
C. Total	37	18553.768		0.0009

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-20.45872	6.463861	-3.17	0.0031
% of Building Area	0.7808511	0.21539	3.63	0.0009

RSquare	0.267439
RSquare Adj	0.24709
Root Mean Square Error	19.43062
Mean of Response	-0.00042
Observations (or Sum Wgts)	38

Figure A.28 Bivariate Fit of Stair Use by % of Building Area



Analysis of Variance

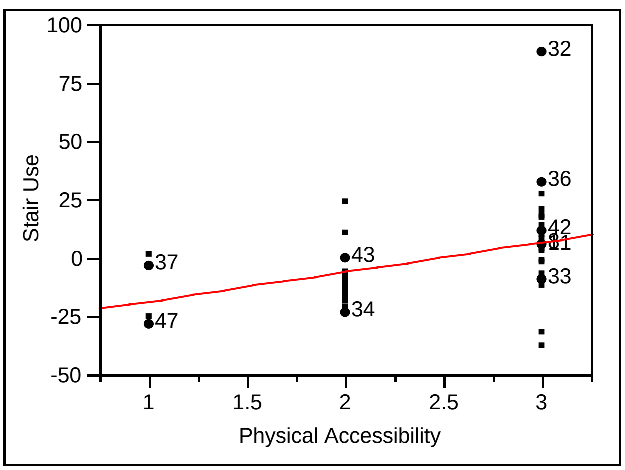
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	5483.190	5483.19	15.1022
Error	36	13070.577	363.07	Prob > F
C. Total	37	18553.768		0.0004

RSquare	0.29553
RSquare Adj	0.275961
Root Mean Square Error	19.05444
Mean of Response	-0.00042
Observations (or Sum Wgts)	38

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-17.95883	5.55961	-3.23	0.0026
% of Total Occupant Load	0.6870225	0.176787	3.89	0.0004

Figure A.29 Bivariate Fit of Stair Use by % of Total Occupant Load



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	2794.893	2794.89	6.3847
Error	36	15758.875	437.75	Prob > F
C. Total	37	18553.768		0.0160

RSquare	0.150637
RSquare Adj	0.127044
Root Mean Square Error	20.92239
Mean of Response	-0.00042
Observations (or Sum Wgts)	38

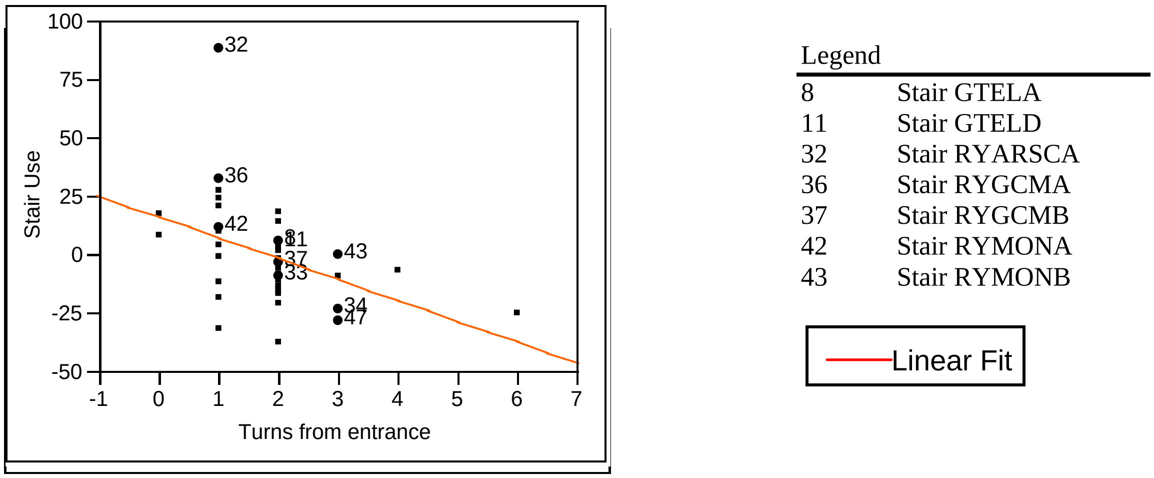
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-31.02265	12.73778	-2.44	0.0200
Physical Accessibility	12.675749	5.016519	2.53	0.0160

Figure A.30 Bivariate Fit of Stair Use By Physical Accessibility

Legend
8 Stair GTELA
11 Stair GTELD
32 Stair RYARSCA
36 Stair RYGCMA
37 Stair RYGCMB
42 Stair RYMONA
43 Stair RYMONB

Linear Fit



Analysis of Variance

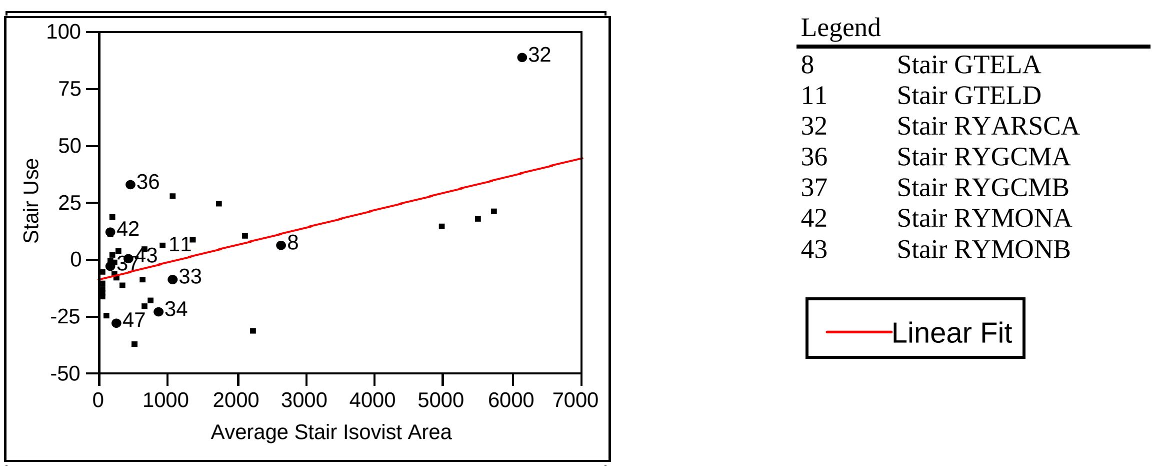
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	6092.112	6092.11	17.5993
Error	36	12461.656	346.16	Prob > F
C. Total	37	18553.768		0.0002

RSquare	0.328349
RSquare Adj	0.309692
Root Mean Square Error	18.6053
Mean of Response	-0.00042
Observations (or Sum Wgts)	38

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-8.909455	3.690433	-2.41	0.0210
Average Stair Isovist Area	0.007634	0.00182	4.20	0.0002

Figure A. 31 Bivariate Fit of Stair Use by Average Stair Isovist Area



Analysis of Variance

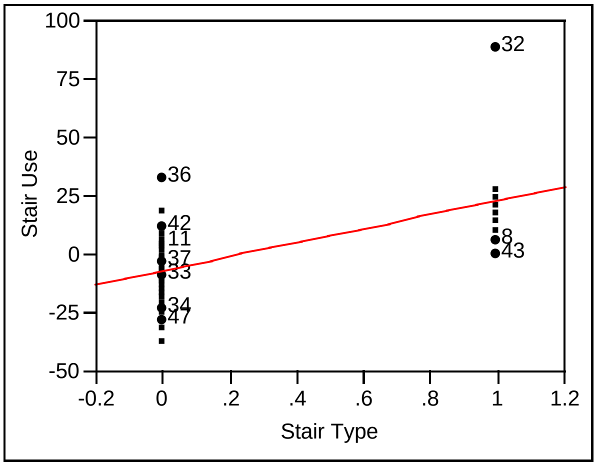
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	3470.133	3470.13	8.2821
Error	36	15083.634	418.99	Prob > F
C. Total	37	18553.768		0.0067

RSquare	0.187031
RSquare Adj	0.164449
Root Mean Square Error	20.46924
Mean of Response	-0.00042
Observations (or Sum Wgts)	38

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	16.17835	6.529205	2.48	0.0180
Turns from entrance	-8.910048	3.096055	-2.88	0.0067

Figure A.32 Bivariate Fit of Stair Use by Turns from Entrance



Legend

8	Stair GTELA
11	Stair GTELD
32	Stair RYARSCA
36	Stair RYGCMA
37	Stair RYGCMB
42	Stair RYMONA
43	Stair RYMONB

Linear Fit

Analysis of Variance

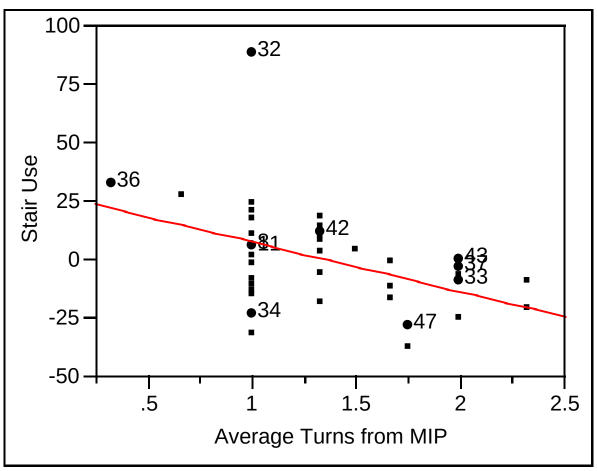
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	6232.319	6232.32	18.2092
Error	36	12321.448	342.26	Prob > F
C. Total	37	18553.768		0.0001

RSquare	0.335906
RSquare Adj	0.317459
Root Mean Square Error	18.50034
Mean of Response	-0.00042
Observations (or Sum Wgts)	38

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-7.134787	3.435426	-2.08	0.0450
Stair Type	30.122874	7.05913	4.27	0.0001

Figure A.33 Bivariate Fit of Stair Use by Stair Type



Legend

8	Stair GTELA
11	Stair GTELD
32	Stair RYARSCA
36	Stair RYGCMA
37	Stair RYGCMB
42	Stair RYMONA
43	Stair RYMONB

Linear Fit

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	3643.241	3643.24	8.7962
Error	36	14910.527	414.18	Prob > F
C. Total	37	18553.768		0.0053

RSquare	0.196361
RSquare Adj	0.174038
Root Mean Square Error	20.35144
Mean of Response	-0.00042
Observations (or Sum Wgts)	38

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	28.766893	10.24599	2.81	0.0080
Average Turns from MIP	-21.30497	7.183436	-2.97	0.0053

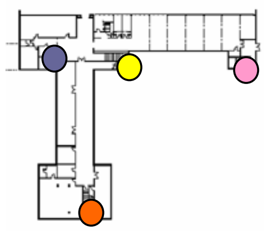
Figure A.34 Bivariate Fit of Stair Use by Average Turns from MIP

APPENDIX B: SUPPLEMENTARY DATA BUILDING, STAIR, AND ELEVATOR DATA SHEETS

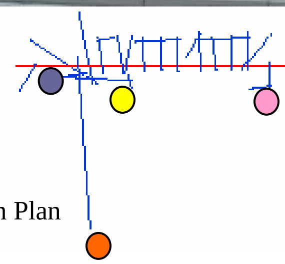
Institution	Georgia Institute of Technology	Building ID	**GTCOA**
Building Name	College of Architecture		
Address	247 Fourth Street NW Atlanta, Georgia		

Number of Stairs	6
Number of Elevators	1
Toronto Building Area (sf)	166186
% Stair Use	87.1%
% Elevator Use	12.9%

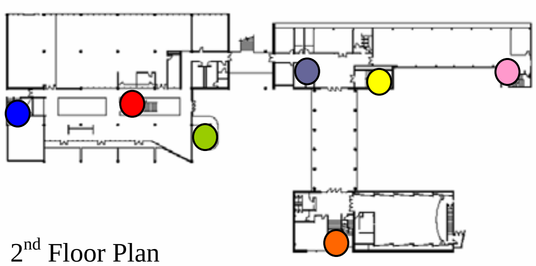
- GTCOAA
- GTCOAB
- GTCOAC
- GTCOAD
- GTCOAE
- GTCOAF
- GTCOAELV



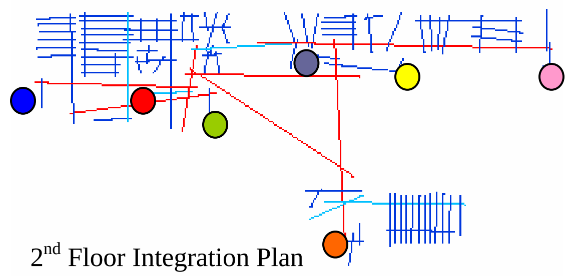
1st Floor Plan



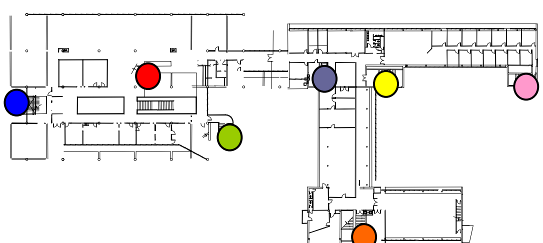
1st Floor Integration Plan



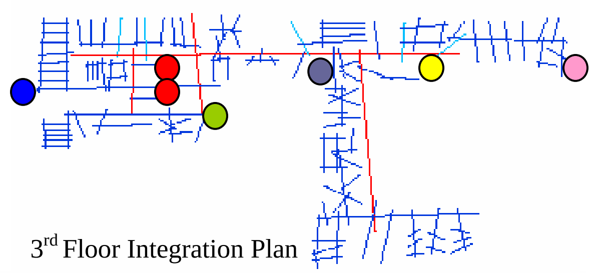
2nd Floor Plan



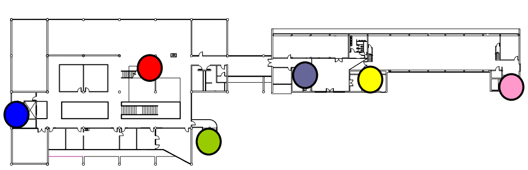
2nd Floor Integration Plan



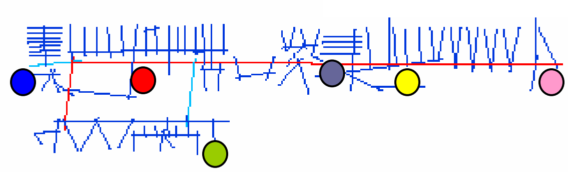
3rd Floor Plan



3rd Floor Integration Plan



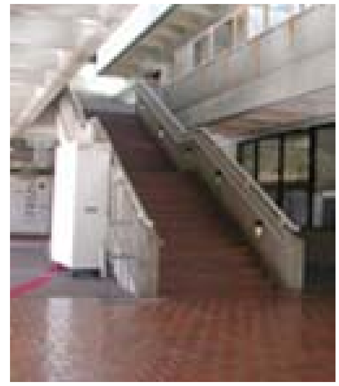
4th Floor Plan



4th Floor Integration Plan

Institution	Georgia Institute of Technology	Stair ID	**GTCOAA**
Building Name	College of Architecture	% of Total Building	**33.1 %**
Address	247 Fourth Street NW Atlanta, Georgia	Vertical Circulation	

Stair Width (in)	88
Riser Height (in)	6.25
Tread Width (in)	11.98
Landing (in) Length	55.9
Number of Steps between Landings	13
Number of Landings between Floors	1
Floor to Floor Height	13” 5”
Handrail Height (in)	32
Guard Height (in)	44



Stair Construction	Concrete
Wall Finish	Atrium, Poured Concrete
Riser Finish	Quarry Tile
Tread Finish	Quarry Tile
Lighting Type	Daylight
Average Illumination (ftc)	25
Minimum Illumination (ftc)	18
Maintenance	8
View	Atrium & Exterior
Art/Displays	Yes
Access	Public
Nosing Contrast	No
Non-slip Treads	Yes

Effective Area (EA)			Occupant Load (OL)	
1st floor	NA	sf	1st floor	NA
2nd floor	12590	sf	2nd floor	104
3rd floor	19994	sf	3rd floor	108
4th floor	13647	sf	4th floor	94
Total Effective Area	46231	sf	Total Occupant Load	306
Total EA as % of Total Building Area	37.0 %		Total OL as % of Total Building OL	24.2 %

Distance to Closest Entry (ft) 31.5

Institution	Georgia Institute of Technology	Stair ID	**GTCOAB**
Building Name	College of Architecture	% of Total Building	**11.9 %**
Address	247 Fourth Street NW Atlanta, Georgia	Vertical Circulation	

Stair Width (in)	56
Riser Height (in)	6
Tread Width (in)	13.25
Landing (in) Length	97.5
Number of Steps between Landings	13
Number of Landings between Floors	1
Floor to Floor Height	13’ 0”
Handrail Height (in)	32
Guard Height (in)	43

Stair Construction	Poured Concrete
Wall Finish	Poured Concrete
Riser Finish	Poured Concrete
Tread Finish	Poured Concrete
Lighting Type	Daylight
Average Illumination (ftc)	11
Minimum Illumination (ftc)	3
Maintenance	7
View	Yes
Art	No
Access	Public
Nosing Contrast	No
Non-slip Treads	Yes

Effective Area (EA)			Occupant Load (OL)	
1st floor	NA	sf	1st floor	NA
2nd floor	17994	sf	2nd floor	66
3rd floor	3235	sf	3rd floor	151
4th floor	29434	sf	4th floor	69
Total Effective Area	24172	sf	Total Occupant Load	286
Total EA as % of Total Building Area	19.3	%	Total OL as % of Total Building OL	22.6 %

Distance to Closest Entry (ft) NA

Institution	Georgia Institute of Technology	Stair ID	**GTCOAC**
Building Name	College of Architecture	% of Total Building	**4.3 %**
Address	247 Fourth Street NW Atlanta, Georgia	Vertical Circulation	


Stair Width (in)	57
Riser Height (in)	6.25
Tread Width (in)	12
Landing (in) Length	65
Number of Steps between Landings	13
Number of Landings between Floors	1
Floor to Floor Height	13” 5”
Handrail Height (in)	31.5
Guard Height (in)	42

Stair Construction	Poured Concrete
Wall Finish	Poured Concrete
Riser Finish	Poured Concrete
Tread Finish	Poured Concrete
Lighting Type	Daylight
Average Illumination (ftc)	300
Minimum Illumination (ftc)	60
Maintenance	7
View	Yes
Art	No
Access	Public
Nosing Contrast	No
Non-slip Treads	Yes

Effective Area (EA)			Occupant Load (OL)	
1st floor	NA	sf	1st floor	NA
2nd floor	NA	sf	2nd floor	NA
3rd floor	361	sf	3rd floor	16
4th floor	361	sf	4th floor	9
Total Effective Area	722	sf	Total Occupant Load	40
Total EA as % of Total Building Area	0.5	%	Total OL as % of Total Building OL	3.2%

Distance to Closest Entry (ft) NA – Exterior Stair

Institution	Georgia Institute of Technology	Stair ID	**GTCOAD**
Building Name	College of Architecture	% of Total Building	**17.5 %**
Address	247 Fourth Street NW Atlanta, Georgia	Vertical Circulation	


Stair Width (in)	76.25
Riser Height (in)	6.14
Tread Width (in)	12.75
Landing (in) Length	92.5
Number of Steps between Landings	13
Number of Landings between Floors	1
Floor to Floor Height	13' 3"
Handrail Height (in)	32
Guard Height (in)	36

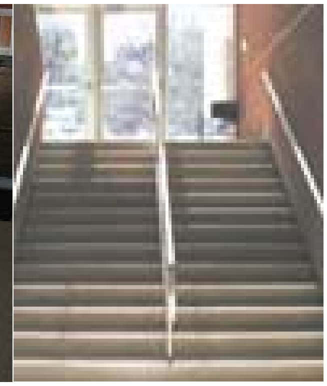
Stair Construction	Concrete
Wall Finish	Ceramic Tile
Riser Finish	Terrazzo
Tread Finish	Terrazzo
Lighting Type	Fluorescent & Daylight
Average Illumination (ftc)	13
Minimum Illumination (ftc)	5
Maintenance	8
View	Yes
Art	No
Access	Public
Nosing Contrast	No
Non-slip Treads	No

Effective Area (EA)		Occupant Load (OL)	
1st floor	7097 sf	1st floor	34
2nd floor	6329 sf	2nd floor	62
3rd floor	8995 sf	3rd floor	87
4th floor	7010 sf	4th floor	112
Total Effective Area	22334 sf	Total Occupant Load	295
Total EA as % of Total Building Area	17.9 %	Total OL as % of Total Building OL	23.3 %

Distance to Closest Entry (ft) 28

Institution	Georgia Institute of Technology	Stair ID	**GTCOAE**
Building Name	College of Architecture	% of Total Building	**19.0 %**
Address	247 Fourth Street NW Atlanta, Georgia	Vertical Circulation	

Stair Width (in)	94.75
Riser Height (in)	6.25
Tread Width (in)	11.92
Landing (in) Length	107
Number of Steps between Landings	13
Number of Landings between Floors	1
Floor to Floor Height	13' 5"
Handrail Height (in)	32
Guard Height (in)	42

Stair Construction	Concrete
Wall Finish	Brick
Riser Finish	Terrazzo
Tread Finish	Terrazzo
Lighting Type	Incandescent & Daylight
Average Illumination (ftc)	15
Minimum Illumination (ftc)	10
Maintenance	7
View	Yes
Art	No
Access	Public
Nosing Contrast	No
Non-slip Treads	No

Effective Area (EA)			Occupant Load (OL)	
1st floor	4701	sf	1st floor	1
2nd floor	6168	sf	2nd floor	120
3rd floor	8145	sf	3rd floor	68
4th floor	NA	sf	4th floor	NA
Total Effective Area	14313	sf	Total Occupant Load	189
Total EA as % of Total Building Area	11.5	%	Total OL as % of Total Building OL	14.9 %

Distance to Closest Entry (ft) 10

Institution	Georgia Institute of Technology	Stair ID	**GTCOAF**
Building Name	College of Architecture	% of Total Building Vertical Circulation	**0.3 %**
Address	247 Fourth Street NW Atlanta, Georgia		

Stair Width (in)	51.75
Riser Height (in)	6.63
Tread Width (in)	12
Landing (in) Length	64
Number of Steps between Landings	12
Number of Landings between Floors	1
Floor to Floor Height	13' 3"
Handrail Height (in)	32
Guard Height (in)	35

Stair Construction	Concrete
Wall Finish	Ceramic tile
Riser Finish	Terrazzo
Tread Finish	Terrazzo
Lighting Type	Incandescent & Daylight
Average Illumination (ftc)	32
Minimum Illumination (ftc)	5
Maintenance	4
View	Yes
Art	No
Access	Some Restricted Access
Nosing Contrast	No
Non-slip Treads	No

Effective Area (EA)		Occupant Load (OL)	
1st floor	2938 sf	1st floor	8
2nd floor	3216 sf	2nd floor	8
3rd floor	3265 sf	3rd floor	10
4th floor	3536 sf	4th floor	40
Total Effective Area	10017 sf	Total Occupant Load	66
Total EA as % of Total Building Area	7.2 %	Total OL as % of Total Building OL	5.2 %

Distance to Closest Entry (ft) 186

Institution	Georgia Institute of Technology	Elevator ID **GTCOAELV**
Building Name	College of Architecture	% of Total building Vertical Circulation **12.9%**
Address	247 Fourth Street NW Atlanta, Georgia	

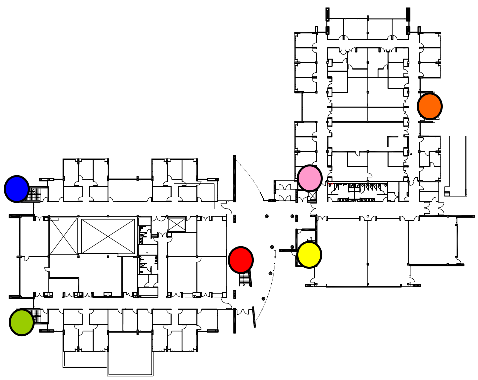
Elevator Cab Width (in)	65.5
Elevator Cab Depth (in	51
Elevator Cab Ceiling Height (in)	105
Elevator Speed (2 floor Full Trip) (sec)	28.73
Distance to Closest Entrance (ft)	25
Total Building Area (sf)	166186
Total Building Occupant Load (spaces)	1182
Elevator Occupant Capacity (persons)	7

Wall Finish	Stainless Steel
Floor Finish	Vinyl
Ceiling Finish	Stainless Steel
Lighting	Incandescent
Illumination (ftc)	24
Maintenance	7
Sound	Voice Floor Announcements
Visual Display	No
Access	Public

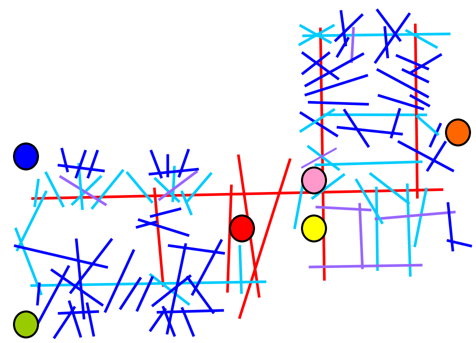
Institution	Georgia Institute of Technology	Building ID	**GTEL**
Building Name	Erskine Love Manufacturing Building		
Address	771 Ferst Street NW Atlanta, Georgia		

Number of Stairs	5
Number of Elevators	1
Toronto Building Area (sf)	115953
% Stair Use	87.5%
% Elevator Use	12.5%

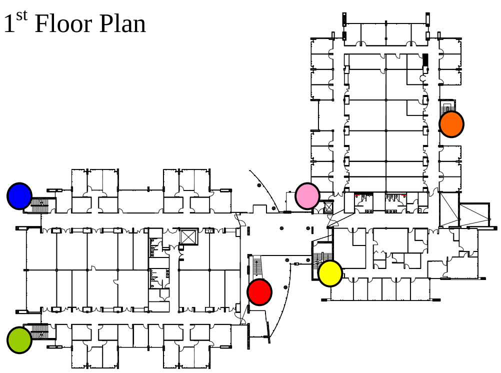
- GTELA
- GTELB
- GTELC
- GTELD
- GTELE
- GTELELV



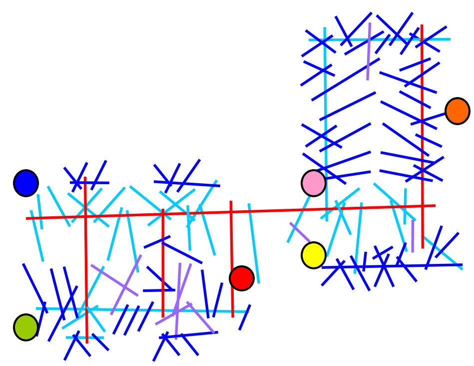
1st Floor Plan



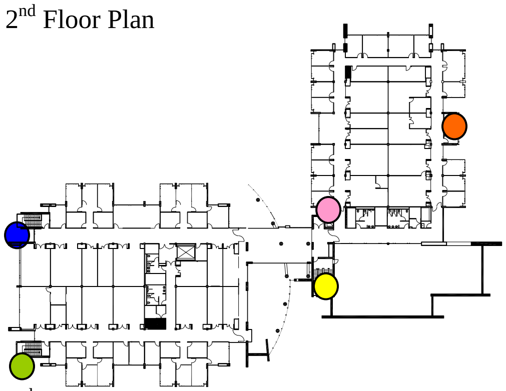
1st Floor Integration Plan



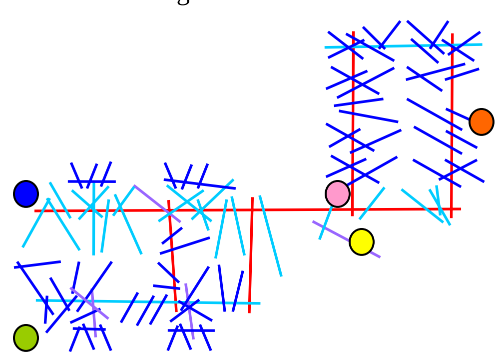
2nd Floor Plan



2nd Floor Integration Plan



3rd Floor Plan



3rd Floor Integration Plan

Institution	Georgia Institute of Technology	Stair ID	**GTELA**
Building Name	Erskine Love Manufacturing Bldg	% of Total Building	**18.9 %**
Address	771 Ferst Drive NW Atlanta, Georgia	Vertical Circulation	

Stair Width (in)	71 to 102
Riser Height (in)	6.75
Tread Width (in)	11.25
Landing (in) Length	61.25
Number of Steps between Landings	14
Number of Landings between Floors	1
Floor to Floor Height	15’ 9”
Handrail Height (in)	33.5
Guard Height (in)	42.5

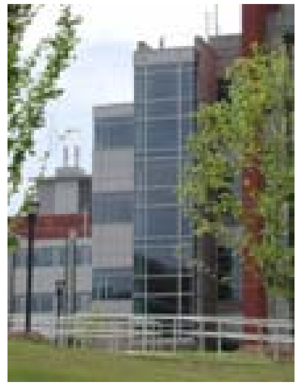
Stair Construction	Steel
Wall Finish	Drywall/Concrete/Glass
Riser Finish	Steel Plate
Tread Finish	Steel Plate
Lighting Type	Incandescent & Daylight
Average Illumination (ftc)	33
Minimum Illumination (ftc)	22
Maintenance	8
View	Atrium & Exterior
Art	Yes
Access	Public
Nosing Contrast	No
Non-lip Treads	Yes

Effective Area (EA)			Occupant Load (OL)	
1st floor	4620	sf	1st floor	46
2nd floor	6827	sf	2nd floor	50
Total Effective Area	12981	sf	Total Occupant Load	96
Total EA as % of Total Building Area	8.7	%	Total OL as % of Total Building OL	10.0 %

Distance to Closest Entry (ft) 20

Institution	Georgia Institute of Technology	Stair ID	**GTELB**
Building Name	Erskine Love Manufacturing Bldg	% of Total Building	**11.8 %**
Address	771 Ferst Drive NW Atlanta, Georgia	Vertical Circulation	

Stair Width (in)	54.32
Riser Height (in)	6.92
Tread Width (in)	11.75
Landing (in) Length	60.5
Number of Steps between Landings	14
Number of Landings between Floors	1
Floor to Floor Height	15’ 8”
Handrail Height (in)	33.5
Guard Height (in)	42.4

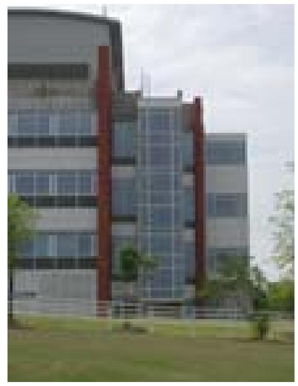


Stair Construction	Concrete
Wall Finish	Concrete
Riser Finish	Vinyl
Tread Finish	Vinyl
Lighting Type	Incandescent & Daylight
Average Illumination (ftc)	43
Minimum Illumination (ftc)	18
Maintenance	9
View	Yes
Art	No
Access	Public
Nosing Contrast	No
Non-slip Treads	Yes

Effective Area (EA)			Occupant Load (OL)	
1st floor	6839	sf	1st floor	34
2nd floor	6839	sf	2nd floor	41
3rd floor	7052	sf	3rd floor	44
Total Effective Area	20730	sf	Total Occupant Load	119
Total EA as % of Total Building Area	17.9	%	Total OL as % of Total Building OL	12.4 %

Distance to Closest Entry (ft) 10

Institution	Georgia Institute of Technology	Stair ID	**GTELC**
Building Name	Erskine Love Manufacturing Bldg	% of Total Building	**5.7 %**
Address	771 Ferst Drive NW Atlanta, Georgia	Vertical Circulation	



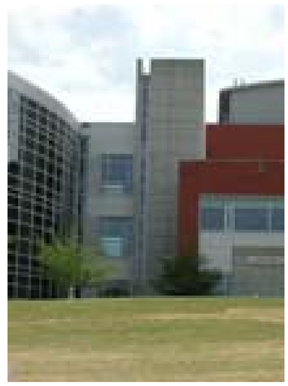

Stair Width (in)	54
Riser Height (in)	7
Tread Width (in)	11.75
Landing (in) Length	60.58
Number of Steps between Landings	14
Number of Landings between Floors	1
Floor to Floor Height	15' 9"
Handrail Height (in)	33.5
Guard Height (in)	42.5

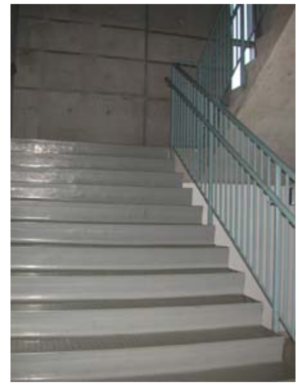
Stair Construction	Concrete
Wall Finish	Concrete
Riser Finish	Vinyl
Tread Finish	Vinyl
Lighting Type	Incandescent & Daylight
Average Illumination (ftc)	36
Minimum Illumination (ftc)	18
Maintenance	8
View	Exterior
Art	No
Access	Public
Nosing Contrast	No
Non-slip Treads	Yes

Effective Area (EA)		Occupant Load (OL)	
1st floor	6666 sf	1st floor	50
2nd floor	6666 sf	2nd floor	33
3rd floor	9225 sf	3rd floor	49
Total Effective Area	22557 sf	Total Occupant Load	132
Total EA as % of Total Building Area	19.5 %	Total OL as % of Total Building OL	13.8 %

Distance to Closest Entry (ft) 163

Institution	Georgia Institute of Technology	Stair ID	**GTELD**
Building Name	Erskine Love Manufacturing Bldg	% of Total Building	**35.5 %**
Address	771 Ferst Drive NW Atlanta, Georgia	Vertical Circulation	





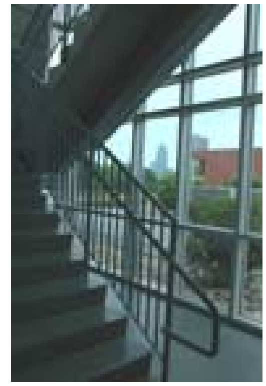
Stair Width (in)	74.75
Riser Height (in)	7
Tread Width (in)	11.92
Landing (in) Length	74
Number of Steps between Landings	14
Number of Landings between Floors	1
Floor to Floor Height	15’ 9”
Handrail Height (in)	33.5
Guard Height (in)	42

Stair Construction	Concrete
Wall Finish	Concrete
Riser Finish	Vinyl
Tread Finish	Vinyl
Lighting Type	Incandescent
Average Illumination (ftc)	3
Minimum Illumination (ftc)	2
Maintenance	8
View	Yes
Art	No
Access	Public
Nosing Contrast	No
Non-slip Treads	Yes

Effective Area (EA)		Occupant Load (OL)	
1st floor	13684 sf	1st floor	188
2nd floor	11258 sf	2nd floor	99
3rd floor	7211 sf	3rd floor	97
Total Effective Area	32153 sf	Total Occupant Load	384
Total EA as % of Total Building Area	19.5 %	Total OL as % of Total Building OL	40.1 %

Distance to Closest Entry (ft) 98

Institution	Georgia Institute of Technology	Stair ID	**GTELE**
Building Name	Erskine Love Manufacturing Bldg	% of Total Building	**15.6 %**
Address	771 Ferst Drive NW Atlanta, Georgia	Vertical Circulation	

Stair Width (in)	54
Riser Height (in)	6.92
Tread Width (in)	11.92
Landing (in) Length	53.75
Number of Steps between Landings	14
Number of Landings between Floors	1
Floor to Floor Height	15' 9"
Handrail Height (in)	33.5
Guard Height (in)	42

Stair Construction	Concrete
Wall Finish	Drywall/Glass
Riser Finish	Vinyl
Tread Finish	Vinyl
Lighting Type	Incandescent & Daylight
Average Illumination (ftc)	117
Minimum Illumination (ftc)	52
Maintenance	8
View	Exterior
Art	No
Access	Public
Nosing Contrast	No
Non-lip Treads	Yes

Effective Area (EA)			Occupant Load (OL)	
1st floor	11171	sf	1st floor	120
2nd floor	9897	sf	2nd floor	57
3rd floor	7999	sf	3rd floor	50
Total Effective Area	29067	sf	Total Occupant Load	227
Total EA as % of Total Building Area	25.1	%	Total OL as % of Total Building OL	23.7 %

Distance to Closest Entry (ft) 91

Institution	Georgia Institute of Technology	Elevator ID	**GTELELV**
Building Name	Erskine Love Manufacturing Bldg	% of Total Building	**12.5%**
Address	771 Ferst Street NW Atlanta, Georgia	Vertical Circulation	

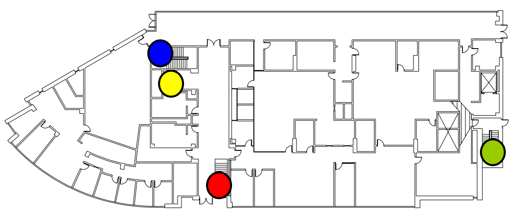
Elevator Cab Width (in)	69.5
Elevator Cab Depth (in	51.5
Elevator Cab Ceiling Height (in)	88
Elevator Speed (2 floor Full Trip) (sec)	32.94
Distance to Closest Entrance (ft)	27
Total Building Area (sf)	115953
Total Building Occupant Load (spaces)	958
Elevator Occupant Capacity (persons)	7

Wall Finish	Plastic Laminate Panels
Floor Finish	Vinyl Tile
Ceiling Finish	Plastic Laminate Panels
Lighting	Fluorescent
Illumination (ftc)	70
Maintenance	10
Sound	No
Visual Display	No
Access	Public

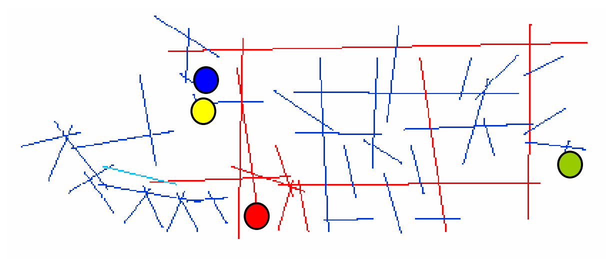
Institution	Georgia Institute of Technology	Building ID	**GTUAW**
Building Name	U A Whitaker Building		
Address	313 Ferst Street NW Atlanta, Georgia		

Number of Stairs	3
Number of Elevators	1
Toronto Building Area (sf)	59236
% Stair Use	76.0 %
% Elevator Use	22.0 %

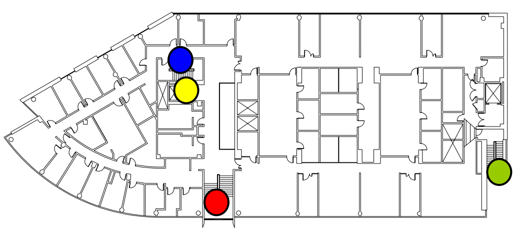
- GTUAWA
- GTUAWB
- GTUAWC
- GTUAWELV



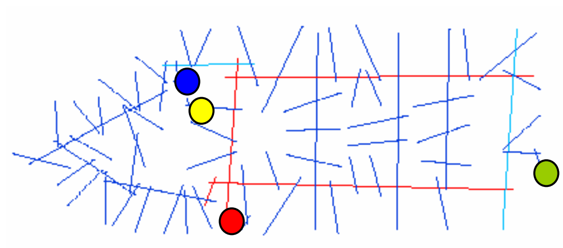
1st Floor Plan



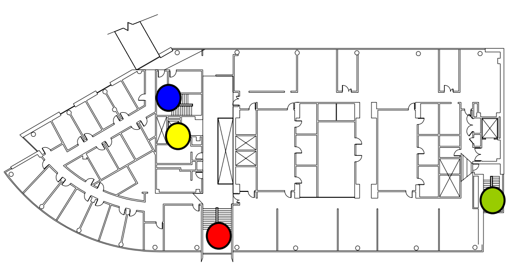
1st Floor Integration Plan



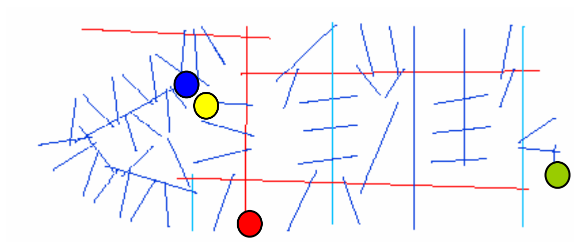
2nd Floor Plan



2nd Floor Integration Plan



3rd Floor Plan



3rd Floor Integration Plan

Institution	Georgia Institute of Technology	Stair ID	**GTUAWA**
Building Name	U A Whitaker Building	% of Total Building Vertical Circulation	**58.6 %**
Address	313 Ferst Drive NW Atlanta, Georgia		

Stair Width (in)	72
Riser Height (in)	7
Tread Width (in)	12
Landing (in) Length	77
Number of Steps between Landings	12
Number of Landings between Floors	1
Floor to Floor Height	14’ 0”
Handrail Height (in)	33
Guard Height (in)	42

Stair Construction	Steel with Concrete Pans
Wall Finish	Painted Drywall
Riser Finish	Painted Drywall
Tread Finish	Slate Tile
Lighting Type	Fluorescent & Daylight
Average Illumination (ftc)	136
Minimum Illumination (ftc)	25
Maintenance	9
View	Interior Lobby & Exterior
Art	No
Access	Public
Nosing Contrast	Yes
Non-slip Treads	Yes

Effective Area (EA)			Occupant Load (OL)	
1st floor	6114	sf	1st floor	21
2nd floor	6895	sf	2nd floor	30
3rd floor	6895	sf	3rd floor	31
Total Effective Area	19904	sf	Total Occupant Load	82
Total EA as % of Total Building Area	33.6	%	Total OL as % of Total Building OL	23.0 %

Distance to Closest Entry (ft) 91

Institution	Georgia Institute of Technology	Stair ID	**GTUAWB**
Building Name	U A Whitaker Building	% of Total Building	**20.6 %**
Address	313 Ferst Drive NW Atlanta, Georgia	Vertical Circulation	

Stair Width (in)	50.38
Riser Height (in)	6.78
Tread Width (in)	12.13
Landing (in) Length	54.5
Number of Steps between Landings	12
Number of Landings between Floors	1
Floor to Floor Height	14' 0"
Handrail Height (in)	33
Guard Height (in)	42

Stair Construction	Steel with Concrete Pans
Wall Finish	Painted Concrete Block
Riser Finish	Painted Steel
Tread Finish	Vinyl
Lighting Type	Florescent
Average Illumination (ftc)	27
Minimum Illumination (ftc)	8
Maintenance	9
View	No
Art	No
Access	Public
Nosing Contrast	No
Non-slip Treads	Yes

Effective Area (EA)		Occupant Load (OL)	
1st floor	6388 sf	1st floor	87
2nd floor	5689 sf	2nd floor	31
3rd floor	5680 sf	3rd floor	36
Total Effective Area	17766 sf	Total Occupant Load	154
Total EA as % of Total Building Area	30.0 %	Total OL as % of Total Building OL	43.1 %

Distance to Closest Entry (ft) 18

Institution	Georgia Institute of Technology	Stair ID	**GTUAWC**
Building Name	U A Whitaker Building	% of Total Building	**4.2 %**
Address	313 Ferst Drive NW Atlanta, Georgia	Vertical Circulation	


Stair Width (in)	43.75
Riser Height (in)	6.88
Tread Width (in)	12.13
Landing (in) Length	54
Number of Steps between Landings	12
Number of Landings between Floors	1
Floor to Floor Height	14’ 0”
Handrail Height (in)	33
Guard Height (in)	42

Stair Construction	Steel with Concrete Pans
Wall Finish	Brick/Glass
Riser Finish	Painted Steel
Tread Finish	Vinyl
Lighting Type	Daylight
Average Illumination (ftc)	300
Minimum Illumination (ftc)	16
Maintenance	9
View	Exterior
Art	No
Access	Not between floors
Nosing Contrast	No
Non-slip Treads	Yes

Effective Area (EA)		Occupant Load (OL)	
1st floor	6262 sf	1st floor	36
2nd floor	7652 sf	2nd floor	45
3rd floor	7652 sf	3rd floor	40
Total Effective Area	21566 sf	Total Occupant Load	121
Total EA as % of Total Building Area	36.4 %	Total OL as % of Total Building OL	33.9 %

Distance to Closest Entry (ft) 204

Institution	Georgia Institute of Technology	Elevator	**GTUAWELV**
Building Name	U A Whitaker Building	% of Total Building	**22.0 %**
Address	313 Ferst Street NW Atlanta, Georgia	Vertical Circulation	

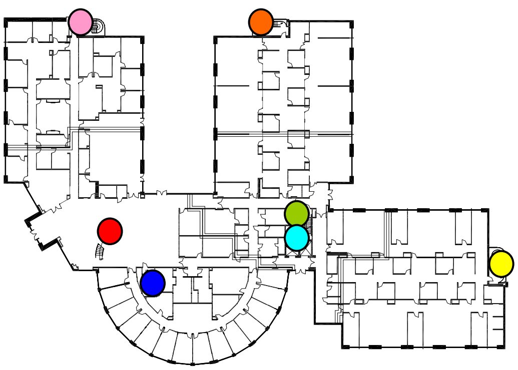
Elevator Cab Width (in)	79.5
Elevator Cab Depth (in	57.5
Elevator Cab Ceiling Height (in)	88
Elevator Speed (2 floor Full Trip) (sec)	27.81
Distance to Closest Entrance (ft)	60
Total Building Area (sf)	59236
Total Building Occupant Load (places)	357
Elevator Occupant Capacity (persons)	9

Wall Finish	Stainless Steel
Floor Finish	Ceramic Tile
Ceiling Finish	Stainless Steel
Lighting	Incandescent
Illumination (ftc)	20
Maintenance	10
Sound	No
Visual Display	No
Access	Public

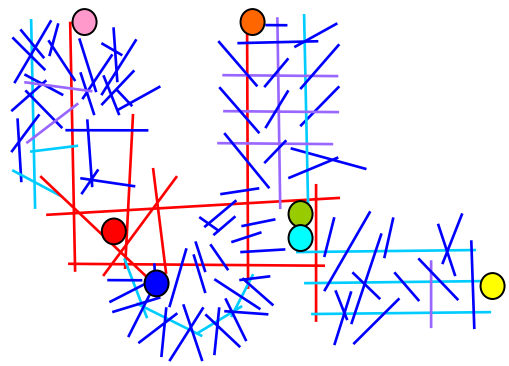
Institution	Georgia Institute of Technology	Building ID	**GTIBB**
Building Name	Parker H. Petit Biotechnology Building		
Address	315 Ferst Street NW Atlanta, Georgia		

Number of Stairs	6
Number of Elevators	2
Toronto Building Area (sf)	121713
% Stair Use	52.6 %
% Elevator Use	47.4 %

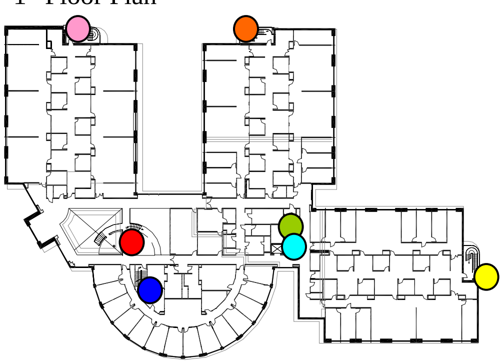
- GTIBBA
- GTIBBB
- GTIBBC
- GTIBBD
- GTIBBE
- GTIBBF
- GTIBBELV1 & GTIBBELV2



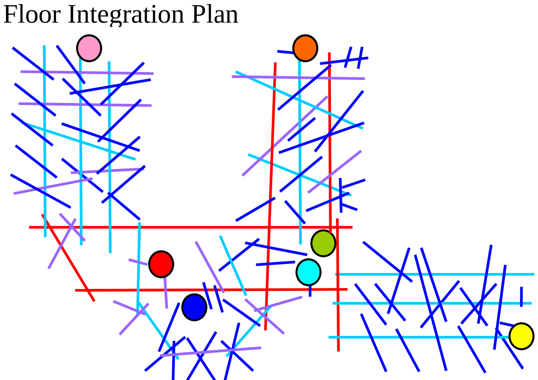
1st Floor Plan



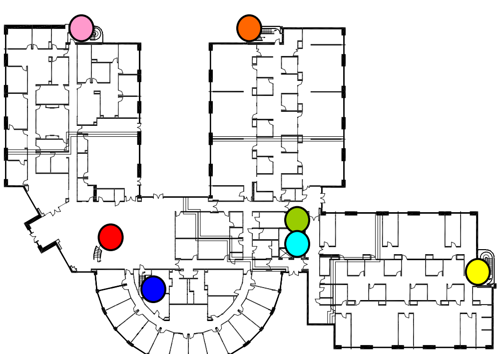
1st Floor Integration Plan



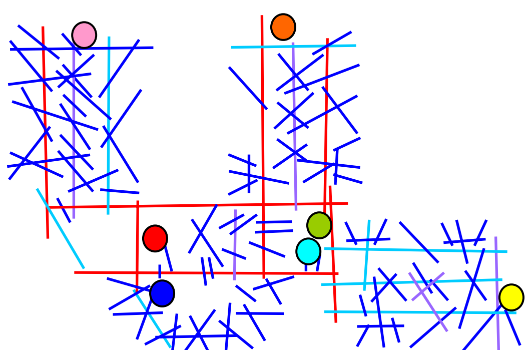
2nd Floor Plan



2nd Floor Integration Plan



3rd Floor Plan



3rd Floor Integration Plan

Institution	Georgia Institute of Technology	Stair ID	**GTIBBA**
Building Name	Parker H. Petit Biotechnology Bldg	% of Total Building	**32.8 %**
Address	315 Ferst Drive NW Atlanta, Georgia	Vertical Circulation	

Stair Width (in)	48
Riser Height (in)	6.88
Tread Width (in)	5 to 14 wedge-shaped
Landing (in) Length	71
Number of Steps between Landings	15
Number of Landings between Floors	1
Floor to Floor Height	17' 3"
Handrail Height (in)	32
Guard Height (in)	41.5

Stair Construction	Steel with Concrete Pans
Wall Finish	Painted Drywall
Riser Finish	Vinyl
Tread Finish	Vinyl
Lighting Type	Incandescent & Daylight
Average Illumination (ftc)	83
Minimum Illumination (ftc)	54
Maintenance	9
View	Atrium/ Exterior
Art	Yes
Access	Public
Nosing Contrast	No
Non-slip Treads	Yes

Effective Area (EA)			Occupant Load (OL)	
1st floor	7076	sf	1st floor	95
2nd floor	2567	sf	2nd floor	2
3rd floor	3338	sf	3rd floor	12
Total Effective Area	12981	sf	Total Occupant Load	109
Total EA as % of Total Building Area	8.7	%	Total OL as % of Total Building OL	19.0 %

Distance to Closest Entry (ft) 20

Institution	Georgia Institute of Technology	Stair ID	**GTIBBB**
Building Name	Parker H. Petit Biotechnology Bldg	% of Total Building	**1.1 %**
Address	315 Ferst Drive NW Atlanta, Georgia	Vertical Circulation	

Stair Width (in)	39.75
Riser Height (in)	6.88
Tread Width (in)	12
Landing (in) Length	41
Number of Steps between Landings	12
Number of Landings between Floors	1
Floor to Floor Height	17’ 3”
Handrail Height (in)	34
Guard Height (in)	42

Stair Construction	Steel with Concrete Pans
Wall Finish	Painted Drywall
Riser Finish	Vinyl
Tread Finish	Vinyl
Lighting Type	Fluorescent
Average Illumination (ftc)	35
Minimum Illumination (ftc)	25
Maintenance	8
View	No
Art	No
Access	Public
Nosing Contrast	No
Non-slip Treads	Yes

Effective Area (EA)		Occupant Load (OL)	
1st floor	9897 sf	1st floor	34
2nd floor	9328 sf	2nd floor	39
3rd floor	8784 sf	3rd floor	19
Total Effective Area	28009 sf	Total Occupant Load	92
Total EA as % of Total Building Area	18.5 %	Total OL as % of Total Building OL	16.1 %

Distance to Closest Entry (ft) 16

Institution	Georgia Institute of Technology	Stair ID	**GTIBBC**
Building Name	Parker H. Petit Biotechnology Bldg	% of Total Building	**8.5 %**
Address	315 Ferst Drive NW Atlanta, Georgia	Vertical Circulation	

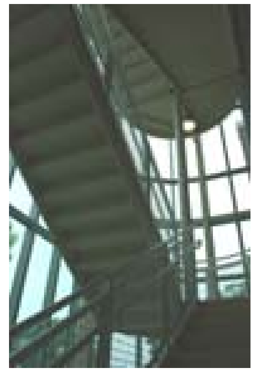
Stair Width (in)	39.75
Riser Height (in)	6.88
Tread Width (in)	12
Landing (in) Length	41
Number of Steps between Landings	12
Number of Landings between Floors	1
Floor to Floor Height	17’ 3”
Handrail Height (in)	34
Guard Height (in)	42

Stair Construction	Steel with Concrete Pans
Wall Finish	Painted Drywall
Riser Finish	Vinyl
Tread Finish	Vinyl
Lighting Type	Fluorescent
Average Illumination (ftc)	31
Minimum Illumination (ftc)	15
Maintenance	8
View	No
Art	No
Access	Public
Nosing Contrast	No
Non-slip Treads	Yes

Effective Area (EA)			Occupant Load (OL)	
1st floor	9994	sf	1st floor	22
2nd floor	8774	sf	2nd floor	16
3rd floor	8774	sf	3rd floor	19
Total Effective Area	27542	sf	Total Occupant Load	57
Total TA as % of Total Building Area	18.4	%	Total OL as % of Total Building OL	9.9 %

Distance to Closest Entry (ft) 8

Institution	Georgia Institute of Technology	Stair ID	**GTIBBD**
Building Name	Parker H. Petit Biotechnology Bldg	% of Total Building	**4.4 %**
Address	315 Ferst Drive NW Atlanta, Georgia	Vertical Circulation	



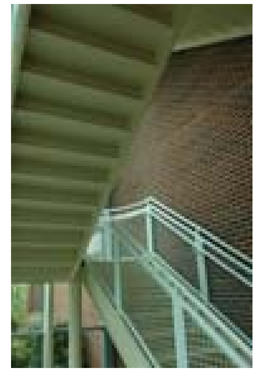
Stair Width (in)	39.75
Riser Height (in)	6.88
Tread Width (in)	12
Landing (in) Length	41
Number of Steps between Landings	12
Number of Landings between Floors	1
Floor to Floor Height	17’ 3”
Handrail Height (in)	34
Guard Height (in)	42

Stair Construction	Steel with Concrete Pans
Wall Finish	Painted Drywall/Glass
Riser Finish	Vinyl
Tread Finish	Vinyl
Lighting Type	Daylight
Average Illumination (ftc)	65
Minimum Illumination (ftc)	28
Maintenance	8
View	Exterior
Art	No
Access	Restricted Access
Nosing Contrast	No
Non-slip Treads	Yes

Effective Area (EA)			Occupant Load (OL)	
1st floor	9604	sf	1st floor	32
2nd floor	10642	sf	2nd floor	40
3rd floor	10642	sf	3rd floor	43
Total Effective Area	30888	sf	Total Occupant Load	115
Total EA as % of Total Building Area	20.7	%	Total OL as % of Total Building OL	20.1 %

Distance to Closest Entry (ft) 200

Institution	Georgia Institute of Technology	Stair ID	**GTIBBE**
Building Name	Parker H. Petit Biotechnology Bldg	% of Total Building	**2.6 %**
Address	315 Ferst Drive NW Atlanta, Georgia	Vertical Circulation	



Stair Width (in)	39.75
Riser Height (in)	6.88
Tread Width (in)	12
Landing (in) Length	41
Number of Steps between Landings	12
Number of Landings between Floors	1
Floor to Floor Height	17’ 3”
Handrail Height (in)	34
Guard Height (in)	42

Stair Construction	Steel with Concrete Pans
Wall Finish	Painted Drywall/Glass
Riser Finish	Vinyl
Tread Finish	Vinyl
Lighting Type	Daylight
Average Illumination (ftc)	88
Minimum Illumination (ftc)	45
Maintenance	8
View	Exterior
Art	No
Access	Restricted Access
Nosing Contrast	No
Non-slip Treads	Yes

Effective Area (EA)			Occupant Load (OL)	
1st floor	7259	sf	1st floor	30
2nd floor	7259	sf	2nd floor	34
3rd floor	7259	sf	3rd floor	34
Total Effective Area	21777	sf	Total Occupant Load	98
Total EA as % of Total Building Area	14.6	%	Total OL as % of Total Building OL	17.1 %

Distance to Closest Entry (ft) 48

Institution	Georgia Institute of Technology	Stair ID	**GTIBBF**
Building Name	Parker H. Petit Biotechnology Bldg	% of Total Building	**3.2 %**
Address	315 Ferst Drive NW Atlanta, Georgia	Vertical Circulation	

Stair Width (in)	39.75
Riser Height (in)	6.88
Tread Width (in)	12
Landing (in) Length	41
Number of Steps between Landings	12
Number of Landings between Floors	1
Floor to Floor Height	17' 3"
Handrail Height (in)	34
Guard Height (in)	42

Stair Construction	Steel with Concrete Pans
Wall Finish	Painted Drywall/Glass
Riser Finish	Vinyl
Tread Finish	Vinyl
Lighting Type	Daylight
Average Illumination (ftc)	84
Minimum Illumination (ftc)	34
Maintenance	8
View	Exterior
Art	No
Access	Restricted Access
Nosing Contrast	No
Non-slip Treads	Yes

Effective Area (EA)		Occupant Load (OL)	
1st floor	7603 sf	1st floor	18
2nd floor	10351 sf	2nd floor	40
3rd floor	10351 sf	3rd floor	44
Total Effective Area	28305 sf	Total Occupant Load	102
Total EA as % of Total Building Area	18.9 %	Total OL as % of Total Building OL	17.8 %

Distance to Closest Entry (ft) 3

Institution	Georgia Institute of Technology	Elevator	**GTIBBELV1**
Building Name	Parker H. Petit Biotechnology Bldg	% of Total Building	**21.0 %**
Address	315 Ferst Street NW Atlanta, Georgia	Vertical Circulation	

Elevator Cab Width (in)	79.5
Elevator Cab Depth (in	56.5
Elevator Cab Ceiling Height (in)	96
Elevator Speed (2 floor Full Trip) (sec)	24.62
Distance to Closest Entrance (ft)	32
Total Building Area (sf)	121713
Total Building Occupant Load (spaces)	573
Elevator Occupant Capacity (persons)	9

Wall Finish	Stainless Steel
Floor Finish	Carpet
Ceiling Finish	Stainless Steel
Lighting	Incandescent
Illumination (ftc)	19
Maintenance	9
Sound	No
Visual Display	No
Access	Public

Institution	Georgia Institute of Technology	Elevator	**GTIBBELV2**
Building Name	Parker H. Petit Biotechnology Bldg	% of Total Building Vertical Circulation	**26.4 %**
Address	315 Ferst Street NW Atlanta, Georgia		

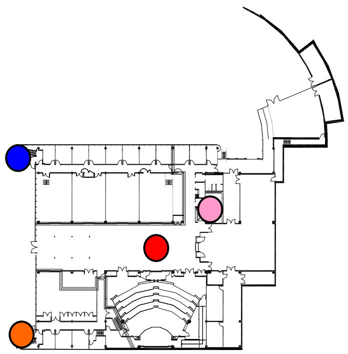
Elevator Cab Width (in)	67.5
Elevator Cab Depth (in	93.5
Elevator Cab Ceiling Height (in)	113
Elevator Speed (2 floor Full Trip) (sec)	27.81
Distance to Closest Entrance (ft)	22
Total Building Area (sf)	121713
Total Building Occupant Load (spaces)	573
Elevator Occupant Capacity (persons)	13

Wall Finish	Stainless Steel
Floor Finish	Vinyl Tile
Ceiling Finish	Stainless Steel
Lighting	Incandescent
Illumination (ftc)	10
Maintenance	9
Sound	No
Visual Display	No
Access	Public

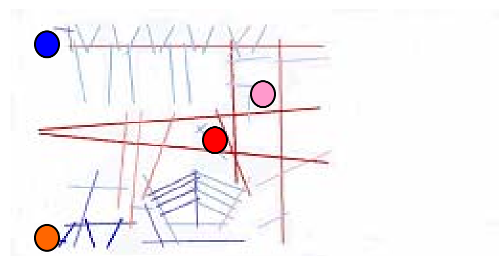
Institution	Georgia Institute of Technology	Building ID	**GTMARC**
Building Name	College of Architecture		
Address	813 Ferst Street NW Atlanta, Georgia		

Number of Stairs	5
Number of Elevators	1
Toronto Building Area (sf)	116428
% Stair Use	66.5 %
% Elevator Use	33.5 %

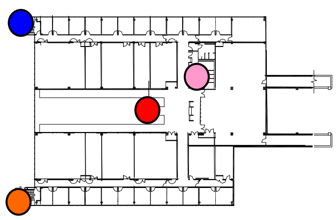
- GTMARCA (red)
- GTMARCB (blue)
- GTMARCC (green)
- GTMARCD (yellow)
- GTMARCE (orange)
- GTMARCELV (pink)



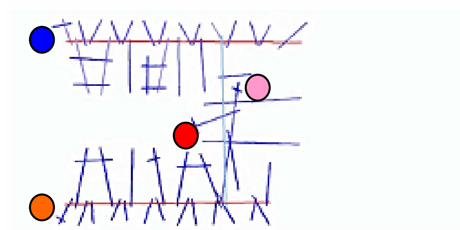
1st Floor Plan



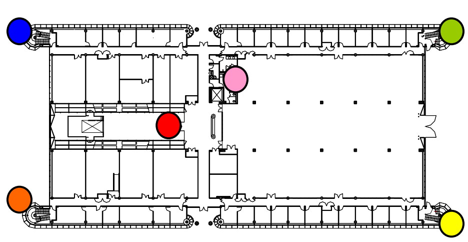
1st Floor Integration Plan



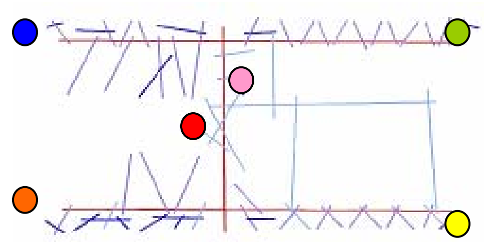
2nd Floor Plan



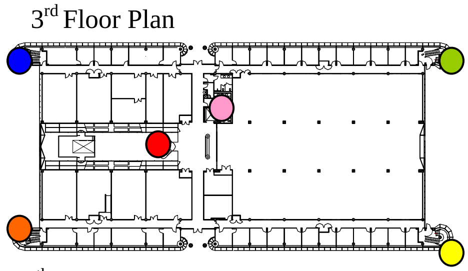
2nd Floor Integration Plan



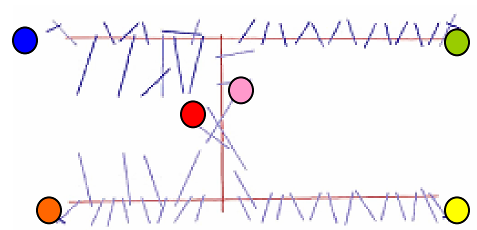
3rd Floor Plan



3rd Floor Integration Plan



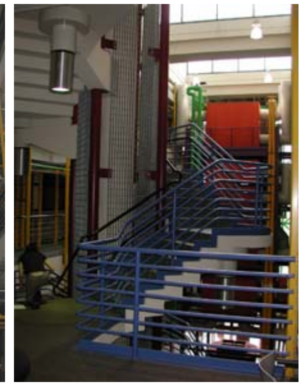
4th Floor Plan



4th Floor Integration Plan

Institution	Georgia Institute of Technology	Stair ID	**GTMARCA**
Building Name	Manufacturing Research Center	% of Total Building	**47.6 %**
Address	813 Ferst Drive NW Atlanta, Georgia	Vertical Circulation	

Stair Width (in)	54
Riser Height (in)	7.25
Tread Width (in)	10.5
Landing (in) Length	65
Number of Steps between Landings	6
Number of Landings between Floors	3
Floor to Floor Height	14' 6"
Handrail Height (in)	31.5
Guard Height (in)	NA

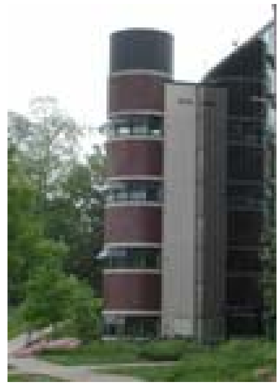
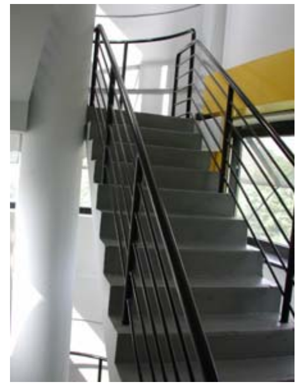
Stair Construction	Concrete
Wall Finish	Painted Drywall/Glass/Concrete
Riser Finish	Ceramic Tile
Tread Finish	Ceramic Tile
Lighting Type	Incandescent
Average Illumination (ftc)	24
Minimum Illumination (ftc)	12
Maintenance	7
View	Atrium
Art	No
Access	Public
Nosing Contrast	No
Non-slip Treads	Yes

Effective Area (EA)			Occupant Load (OL)	
1st floor	15844	sf	1st floor	192
2nd floor	15325	sf	2nd floor	58
3rd floor	13053	sf	3rd floor	78
4th floor	7307	sf	4th floor	72
Total Effective Area	51529	sf	Total Occupant Load	400
Total EA as % of Total Building Area	44.3	%	Total OL as % of Total Building OL	49.0 %

Distance to Closest Entry (ft) 78

Institution	Georgia Institute of Technology	Stair ID	**GTMARCB**
Building Name	Manufacturing Research Center	% of Total Building	**4.3 %**
Address	813 Ferst Drive NW Atlanta, Georgia	Vertical Circulation	

Stair Width (in)	37.35
Riser Height (in)	7
Tread Width (in)	11
Landing (in) Length	46.5
Number of Steps between Landings	12
Number of Landings between Floors	1
Floor to Floor Height	17’ 6”
Handrail Height (in)	34
Guard Height (in)	NA

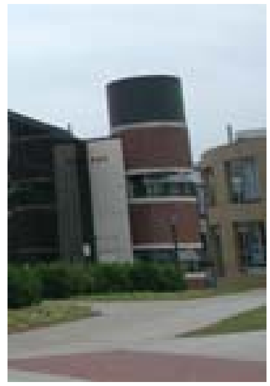



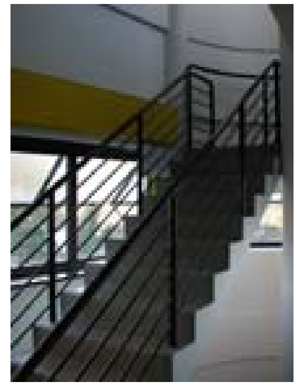
Stair Construction	Concrete
Wall Finish	Painted Concrete
Riser Finish	Painted Concrete
Tread Finish	Painted Concrete
Lighting Type	Fluorescent/ Daylight
Average Illumination (ftc)	18
Minimum Illumination (ftc)	10
Maintenance	9
View	Exterior
Art	No
Access	Public
Nosing Contrast	Yes
Non-slip Treads	Yes

Effective Area (EA)			Occupant Load (OL)	
1st floor	NA	sf	1st floor	NA
2nd floor	NA	sf	2nd floor	NA
3rd floor	7730	sf	3rd floor	25
4th floor	3010	sf	4th floor	9
Total Effective Area	10740	sf	Total Occupant Load	34
Total EA as % of Total Building Area	9.2	%	Total OL as % of Total Building OL	4.2 %

Distance to Closest Entry (ft) 178

Institution	Georgia Institute of Technology	Stair ID	**GTMARCC**
Building Name	Manufacturing Research Center	% of Total Building Vertical Circulation	**3.7 %**
Address	813 Ferst Drive NW Atlanta, Georgia		





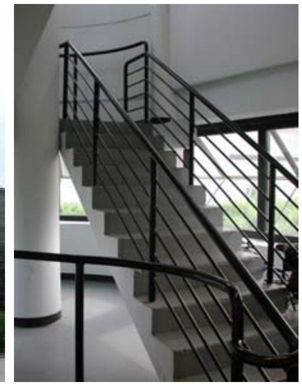
Stair Width (in)	37.25
Riser Height (in)	7
Tread Width (in)	11
Landing (in) Length	46.5
Number of Steps between Landings	12
Number of Landings between Floors	1
Floor to Floor Height	17' 6"
Handrail Height (in)	34
Guard Height (in)	NA

Stair Construction	Concrete
Wall Finish	Painted Concrete
Riser Finish	Painted Concrete
Tread Finish	Painted Concrete
Lighting Type	Fluorescent/Daylight
Average Illumination (ftc)	18
Minimum Illumination (ftc)	10
Maintenance	9
View	Exterior
Art	No
Access	Public
Nosing Contrast	Yes
Non-slip Treads	Yes

Effective Area (EA)			Occupant Load (OL)	
1st floor	3136	sf	1st floor	28
2nd floor	4538	sf	2nd floor	32
3rd floor	6140	sf	3rd floor	58
4th floor	6140	sf	4th floor	54
Total Effective Area	19954	sf	Total Occupant Load	172
Total EA as % of Total Building Area	9.2	%	Total OL as % of Total Building OL	21.1 %

Distance to Closest Entry (ft) 124

Institution	Georgia Institute of Technology	Stair ID	**GTMARCD**
Building Name	Manufacturing Research Center	% of Total Building	**4.1 %**
Address	813 Ferst Drive NW Atlanta, Georgia	Vertical Circulation	

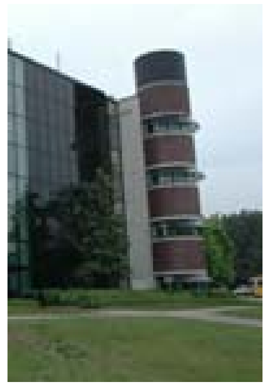
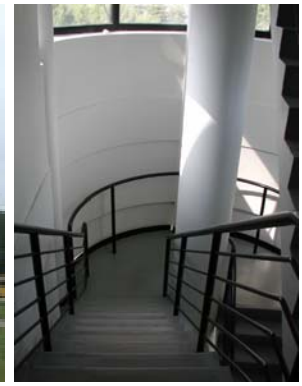
Stair Width (in)	37.25
Riser Height (in)	7
Tread Width (in)	11
Landing (in) Length	46.5
Number of Steps between Landings	12
Number of Landings between Floors	1
Floor to Floor Height	17' 6"
Handrail Height (in)	34
Guard Height (in)	NA

Stair Construction	Concrete
Wall Finish	Painted Concrete
Riser Finish	Painted Concrete
Tread Finish	Painted Concrete
Lighting Type	Fluorescent/Daylight
Average Illumination (ftc)	14
Minimum Illumination (ftc)	14
Maintenance	8
View	Exterior
Art	Yes
Access	Public
Nosing Contrast	Yes
Non-slip Treads	Yes

Effective Area (EA)			Occupant Load (OL)	
1st floor	6180	sf	1st floor	12
2nd floor	5195	sf	2nd floor	54
3rd floor	6154	sf	3rd floor	49
4th floor	6154	sf	4th floor	55
Total Effective Area	23683	sf	Total Occupant Load	170
Total EA as % of Total Building Area	20.3	%	Total OL as % of Total Building OL	20.8 %

Distance to Closest Entry (ft) 124

Institution	Georgia Institute of Technology	Stair ID	**GTMARCE**
Building Name	Manufacturing Research Center	% of Total Building Vertical Circulation	**6.7 %**
Address	813 Ferst Drive NW Atlanta, Georgia		

Stair Width (in)	37.25
Riser Height (in)	7
Tread Width (in)	11
Landing (in) Length	46.5
Number of Steps between Landings	12
Number of Landings between Floors	1
Floor to Floor Height	17' 6"
Handrail Height (in)	34
Guard Height (in)	NA

Stair Construction	Concrete
Wall Finish	Painted Concrete
Riser Finish	Painted Concrete
Tread Finish	Painted Concrete
Lighting Type	Fluorescent/Daylight
Average Illumination (ftc)	17
Minimum Illumination (ftc)	10
Maintenance	9
View	Exterior
Art	Yes
Access	Public
Nosing Contrast	Yes
Non-slip Treads	Yes

Effective Area (EA)			Occupant Load (OL)	
1st floor	NA	sf	1st floor	NA
2nd floor	NA	sf	2nd floor	NA
3rd floor	7514	sf	3rd floor	16
4th floor	3008	sf	4th floor	24
Total Effective Area	10522	sf	Total Occupant Load	40
Total EA as % of Total Building Area	9.0	%	Total OL as % of Total Building OL	4.9 %

Distance to Closest Entry (ft) 177

Institution	Georgia Institute of Technology	Elevator **GTMARCELV**
Building Name	Manufacturing Research Center	% of Total Building **33.5%**
Address	813 Ferst Street NW Atlanta, Georgia	Vertical Circulation

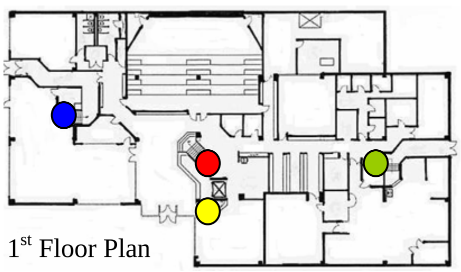
Elevator Cab Width (in)	83.5
Elevator Cab Depth (in	96.5
Elevator Cab Ceiling Height (in)	113
Elevator Speed (2 floor Full Trip) (sec)	36.41
Distance to Closest Entrance (ft)	60
Total Building Area (sf)	116428
Total Building Occupant Load (spaces)	816
Elevator Occupant Capacity (persons)	16

Wall Finish	Plastic Laminate Panels
Floor Finish	Carpet
Ceiling Finish	Plastic Laminate Panels
Lighting	Fluorescent
Illumination (ftc)	2
Maintenance	9
Sound	No
Visual Display	No
Access	Public

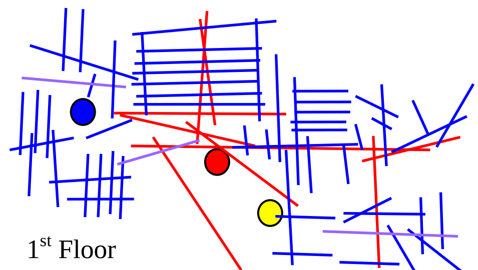
Institution	Ryerson University	Building ID	**RYARSC**
Building Name	Architecture Building		
Address	325 Church Street Toronto, Ontario		

Number of Stairs	3
Number of Elevators	1
Toronto Building Area (sf)	57372
% Stair Use	85.2 %
% Elevator Use	14.8 %

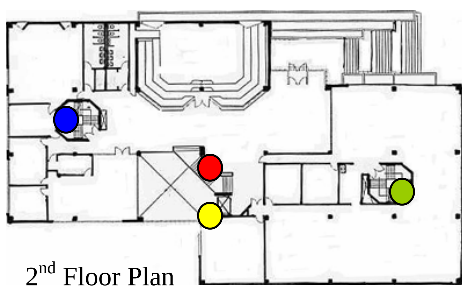
- RYARSCA (red)
- RYARSCB (blue)
- RYARSCC (green)
- RYARSCELV (yellow)



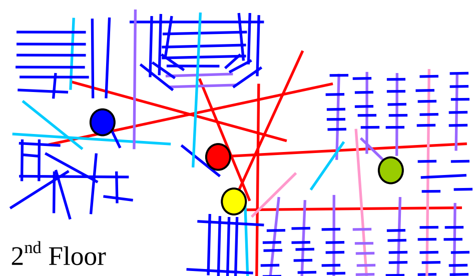
1st Floor Plan



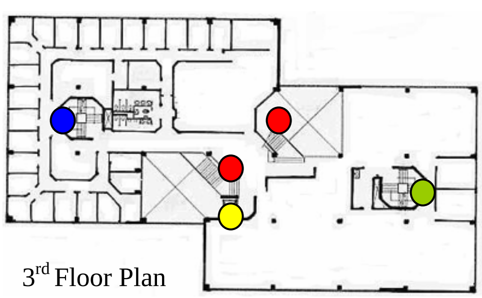
1st Floor Integration Plan



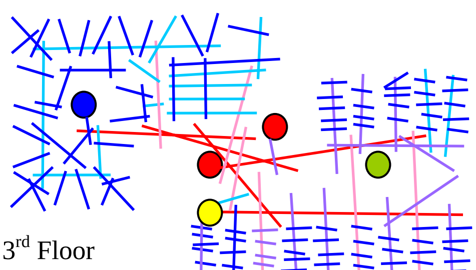
2nd Floor Plan



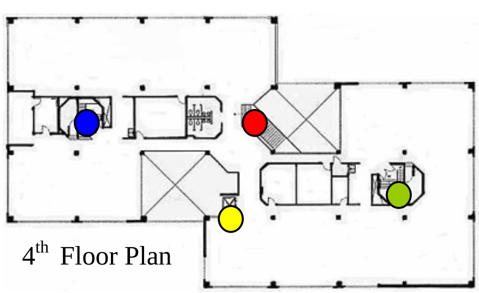
2nd Floor Integration Plan



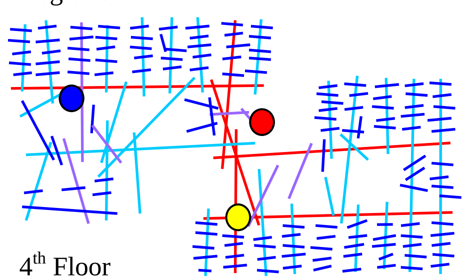
3rd Floor Plan



3rd Floor Integration Plan

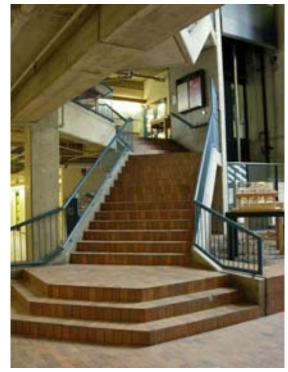


4th Floor Plan



4th Floor Integration Plan

Institution	Ryerson University	Stair ID	**RYARSCA**
Building Name	Architecture Building	% of Total Building Vertical Circulation	**77.6 %**
Address	325 Church Street Toronto, Ontario		

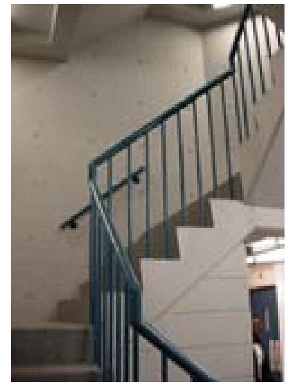
Stair Width (in)	81
Riser Height (in)	7
Tread Width (in)	9
Landing (in) Length	78
Number of Steps between Landings	3 12, 5
Number of Landings between Floors	2
Floor to Floor Height	11' 6"
Handrail Height (in)	40
Guard Height (in)	44

Stair Construction	Concrete
Wall Finish	Drywall, Concrete/Glass
Riser Finish	Quarry Tile
Tread Finish	Quarry Tile
Lighting Type	Incandescent/Daylight
Average Illumination (ftc)	35
Minimum Illumination (ftc)	18
Maintenance	4
View	Exterior
Art	Yes
Access	Public
Nosing Contrast	No
Non-slip Treads	Yes

Effective Area (EA)			Occupant Load (OL)	
1st floor	7321	sf	1st floor	212
2nd floor	5519	sf	2nd floor	167
3rd floor	5016	sf	3rd floor	78
4th floor	5208	sf	4th floor	46
Total Effective Area	23064	sf	Total Occupant Load	503
Total EA as % of Total Building Area	34.7	%	Total OL as % of Total Building OL	46.9 %

Distance to Closest Entry (ft) 64

Institution	Ryerson University	Stair ID	**RYARSCB**
Building Name	Architecture Building	% of Total Building	**5.0 %**
Address	325 Church Street Toronto, Ontario	Vertical Circulation	



Stair Width (in)	87
Riser Height (in)	7
Tread Width (in)	8
Landing (in) Length	65
Number of Steps between Landings	5
Number of Landings between Floors	3
Floor to Floor Height	11’ 6”
Handrail Height (in)	33
Guard Height (in)	38

Stair Construction	Concrete
Wall Finish	Painted Concrete
Riser Finish	Painted Concrete
Tread Finish	Painted Concrete
Lighting Type	Fluorescent
Average Illumination (ftc)	10
Minimum Illumination (ftc)	5
Maintenance	3
View	No
Art	No
Access	Public
Nosing Contrast	No
Non-slip Treads	Yes

Effective Area (EA)			Occupant Load (OL)	
1st floor	3914	sf	1st floor	79
2nd floor	6895	sf	2nd floor	88
3rd floor	5150	sf	3rd floor	32
4th floor	5847	sf	4th floor	71
Total Effective Area	21806	sf	Total Occupant Load	270
Total EA as % of Total Building Area	35.7	%	Total OL as % of Total Building OL	25.2 %

Distance to Closest Entry (ft) 104

Institution	Ryerson University	Stair ID	**RYARSCC**
Building Name	Architecture Building	% of Total Building	**2.5 %**
Address	325 Church Street Toronto, Ontario	Vertical Circulation	

Stair Width (in)	87
Riser Height (in)	7
Tread Width (in)	8
Landing (in) Length	65
Number of Steps between Landings	5
Number of Landings between Floors	3
Floor to Floor Height	11' 6"
Handrail Height (in)	33
Guard Height (in)	38

Stair Construction	Concrete
Wall Finish	Painted Concrete
Riser Finish	Painted Concrete
Tread Finish	Painted Concrete
Lighting Type	Fluorescent
Average Illumination (ftc)	10
Minimum Illumination (ftc)	8
Maintenance	3
View	No
Art	No
Access	Public
Nosing Contrast	No
Non-lip Treads	Yes

Effective Area (EA)			Occupant Load (OL)	
1st floor	5090	sf	1st floor	29
2nd floor	4874	sf	2nd floor	84
3rd floor	6329	sf	3rd floor	103
4th floor	5279	sf	4th floor	83
Total Effective Area	21572	sf	Total Occupant Load	299
Total EA as % of Total Building Area	32.5	%	Total OL as % of Total Building OL	27.9 %

Distance to Closest Entry (ft) 311

Institution	Ryerson University	Elevator **RYARSCELV**
Building Name	Architecture Building	% of Total Building **14.8 %**
Address	325 Church Street Toronto, Ontario	Vertical Circulation

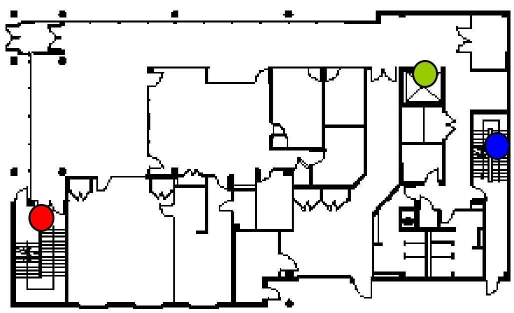
Elevator Cab Width (in)	92
Elevator Cab Depth (in	56
Elevator Cab Ceiling Height (in)	98
Elevator Speed (2 floor Full Trip) (sec)	21.25
Distance to Closest Entrance (ft)	45
Total Building Area (sf)	57372
Total Building Occupant (spaces)	1072
Elevator Occupant Capacity	10

Wall Finish	Plastic Laminate Panels
Floor Finish	Quarry Tile
Ceiling Finish	Lighting Grid
Lighting	Fluorescent/Daylight
Illumination (ftc)	34
Maintenance	4
Sound	No
Visual Display	Atrium
Access	Public

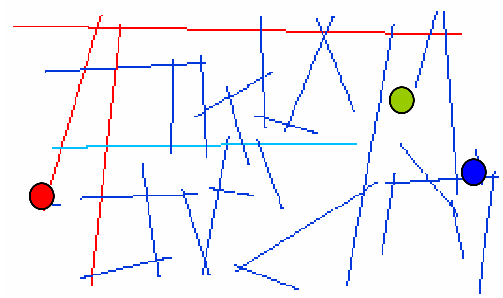
Institution	Ryerson University	Building ID	**RYGCM**
Building Name	Heidelberg Centre, School of Graphic Communications Management		
Address	125 Bond Street Toronto, Ontario		

Number of Stairs	2
Number of Elevators	1
Toronto Building Area (sf)	22115
% Stair Use	74.3 %
% Elevator Use	25.7 %

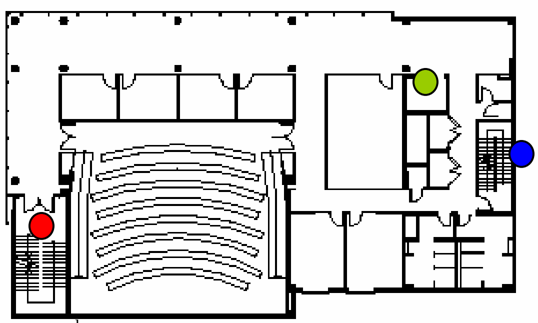
- RYGCMA
- RYGCMB
- RYGCMELV



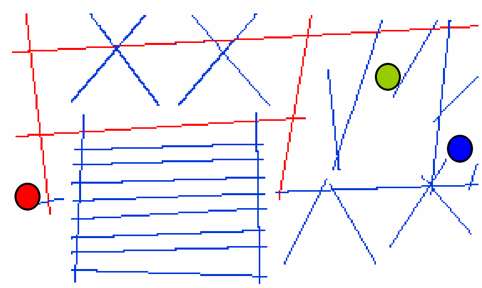
1st Floor Plan



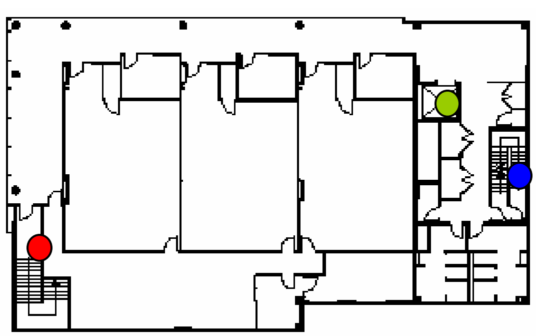
1st Floor Integration Plan



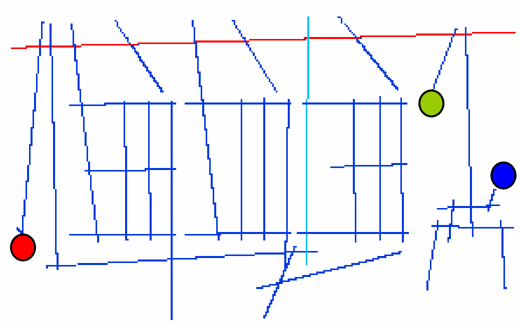
2nd Floor Plan



2nd Floor Integration Plan

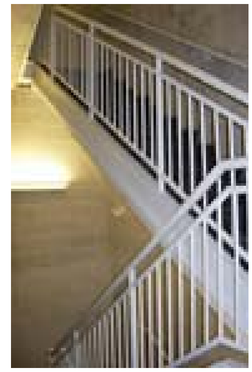


3rd Floor Plan



3rd Floor Integration Plan

Institution	Ryerson University	Stair ID	**RYGCMA**
Building Name	Heidelberg Centre (GCM)	% of Total Building Vertical Circulation	**65.6 %**
Address	125 Bond Street Toronto, Ontario		



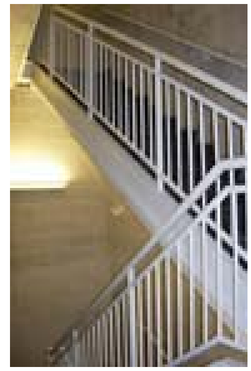
Stair Width (in)	64
Riser Height (in)	7
Tread Width (in)	9
Landing (in) Length	67
Number of Steps between Landings	15
Number of Landings between Floors	1
Floor to Floor Height	17’ 6”
Handrail Height (in)	35
Guard Height (in)	37

Stair Construction	Steel with Concrete Pans
Wall Finish	Painted Drywall
Riser Finish	Vinyl
Tread Finish	Vinyl
Lighting Type	Fluorescent
Average Illumination (ftc)	18
Minimum Illumination (ftc)	10
Maintenance	8
View	No
Art	No
Access	Public
Nosing Contrast	No
Non-slip Treads	Yes

Effective Area (EA)			Occupant Load (OL)	
1st floor	3790	sf	1st floor	39
2nd floor	4625	sf	2nd floor	140
3rd floor	4602	sf	3rd floor	81
Total Effective Area	13017	sf	Total Occupant Load	260
Total EA as % of Total Building Area	58.9	%	Total OL as % of Total Building OL	78.3 %

Distance to Closest Entry (ft) 58

Institution	Ryerson University	Stair ID	**RYGCMB**
Building Name	Heidelberg Centre (GCM)	% of Total Building	**8.7 %**
Address	125 Bond Street Toronto, Ontario	Vertical Circulation	



Stair Width (in)	42
Riser Height (in)	7.25
Tread Width (in)	9.25
Landing (in) Length	44
Number of Steps between Landings	14
Number of Landings between Floors	1
Floor to Floor Height	17' 6"
Handrail Height (in)	41
Guard Height (in)	49

Stair Construction	Steel with Concrete Pans
Wall Finish	Painted Drywall
Riser Finish	Vinyl
Tread Finish	Vinyl
Lighting Type	Fluorescent
Average Illumination (ftc)	10
Minimum Illumination (ftc)	10
Maintenance	8
View	No
Art	No
Access	Public
Nosing Contrast	No
Non-slip Treads	Yes

Effective Area (EA)			Occupant Load (OL)	
1st floor	3468	sf	1st floor	12
2nd floor	2803	sf	2nd floor	20
3rd floor	2827	sf	3rd floor	40
Total Effective Area	9098	sf	Total Occupant Load	72
Total EA as % of Total Building Area	41.1	%	Total OL as % of Total Building OL	21.7 %

Distance to Closest Entry (ft) 146

Institution	Ryerson University	Elevator	**RYGCMELV**
Building Name	Heidelberg Centre (GCM)	% of Total Building	**25.7 %**
Address	125 Bond Street Toronto, Ontario	Vertical Circulation	

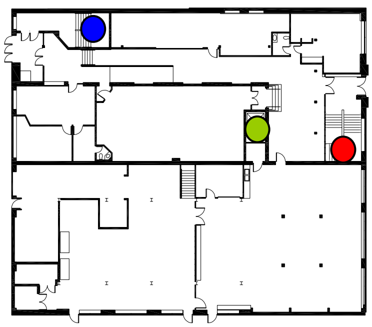
Elevator Cab Width (in)	81
Elevator Cab Depth (in	65
Elevator Cab Ceiling Height (in)	107
Elevator Speed (2 floor Full Trip) (sec)	36.54
Distance to Closest Entrance (ft)	68
Total Building Area (sf)	22115
Total Building Occupant Load (spaces)	332
Elevator Occupant Capacity (persons)	11

Wall Finish	Plastic Laminate Panels
Floor Finish	Vinyl
Ceiling Finish	Metal Panel
Lighting	Incandescent
Illumination (ftc)	34
Maintenance	9
Sound	No
Visual Display	No
Access	Public

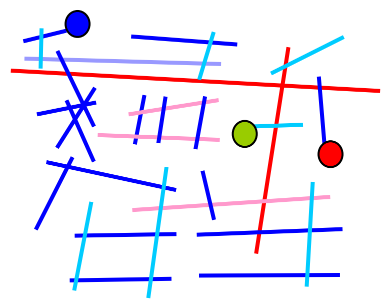
Institution	Ryerson University	Building ID	**RYINT**
Building Name	School of Interior Design		
Address	302 Church Street Toronto, Ontario		

Number of Stairs	2
Number of Elevators	1
Toronto Building Area (sf)	34256
% Stair Use	72.9 %
% Elevator Use	27.1 %

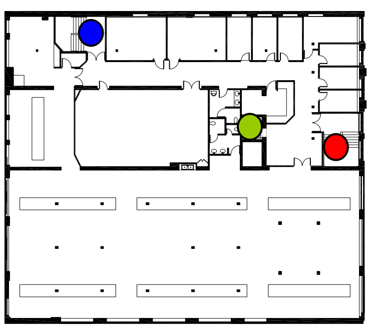
● RYINTA
● RYINTB
● RYINTELV



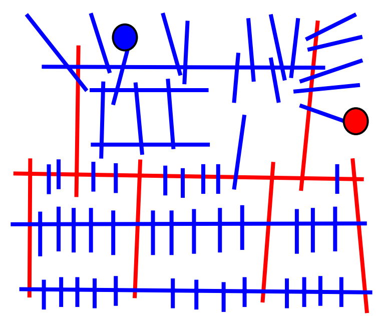
1st Floor Plan



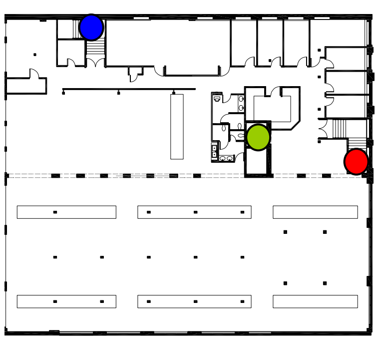
1st Floor Integration Plan



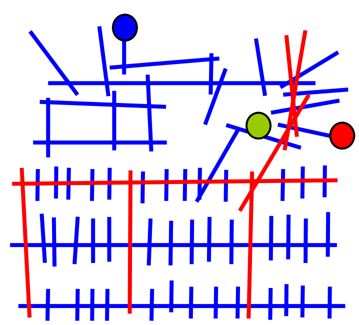
2nd Floor Plan



2nd Floor Integration Plan



3rd Floor Plan



3rd Floor Integration Plan

Institution	Ryerson University	Stair ID	**RYINTA**
Building Name	School of Interior Design	% of Total Building	**50.8 %**
Address	302 Church Street Toronto, Ontario	Vertical Circulation	

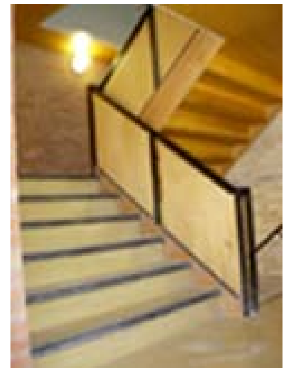
Stair Width (in)	60
Riser Height (in)	7.5
Tread Width (in)	10.25
Landing (in) Length	72
Number of Steps between Landings	7
Number of Landings between Floors	2
Floor to Floor Height	13' 1"
Handrail Height (in)	40.5
Guard Height (in)	NA

Stair Construction	Steel with Concrete Pans
Wall Finish	Brick
Riser Finish	Painted Steel
Tread Finish	Sealed Concrete
Lighting Type	Fluorescent/Daylight
Average Illumination (ftc)	50
Minimum Illumination (ftc)	50
Maintenance	7
View	Exterior/Lobby
Art	No
Access	Public
Nosing Contrast	No
Non-lip Treads	Yes

Effective Area (EA)		Occupant Load (OL)	
1st floor	9177 sf	1st floor	125
2nd floor	5763 sf	2nd floor	74
3rd floor	8034 sf	3rd floor	94
Total Effective Area	22974 sf	Total Occupant Load	293
Total EA as % of Total Building Area	67.1 %	Total OL as % of Total Building OL	66.1 %

Distance to Closest Entry (ft) 10

Institution	Ryerson University	Stair ID	**RYINTB**
Building Name	School of Interior Design	% of Total Building	**22.1 %**
Address	302 Church Street Toronto, Ontario	Vertical Circulation	



Stair Width (in)	64.5
Riser Width (in)	8
Tread Width (in)	9
Landing (in) Length	72
Number of Steps between Landings	6
Number of Landings between Floors	2
Floor to Floor Height	13' 1"
Handrail Height (in)	33
Guard Height (in)	NA

Stair Construction	Steel with Concrete Pans
Wall Finish	Brick
Riser Finish	Painted Steel
Tread Finish	Vinyl
Lighting Type	Incandescent
Average Illumination (ftc)	3
Minimum Illumination (ftc)	2
Maintenance	8
View	No
Art	Yes
Access	Public
Nosing Contrast	Yes
Non-slip Treads	Yes

Effective Area (EA)		Occupant Load (OL)	
1st floor	2242 sf	1st floor	24
2nd floor	5656 sf	2nd floor	94
3rd floor	3384 sf	3rd floor	32
Total Effective Area	11282 sf	Total Occupant Load	150
Total EA as % of Total Building Area	32.9 %	Total OL as % of Total Building OL	33.9 %

Distance to Closest Entry (ft) 15

Institution	Ryerson University	Elevator ID	**GTINTELV**
Building Name	School of Interior Design	% of Total Building	**27.1 %**
Address	302 Church Street Toronto, Ontario	Vertical Circulation	

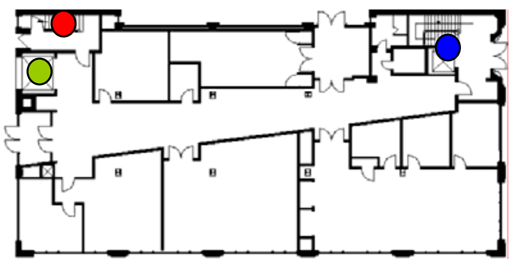
Elevator Cab Width (in)	69
Elevator Cab Depth (in	52
Elevator Cab Ceiling Height (in)	92
Elevator Speed (2 floor Full Trip) (sec)	22.42
Distance to Closest Entrance (ft)	36
Total Building Area (sf)	34256
Total Building Occupant Load (spaces)	443
Elevator Occupant Capacity (persons)	7

Wall Finish	Plastic Laminate Panels
Floor Finish	Vinyl Tile
Ceiling Finish	Lighting Grid
Lighting	Fluorescent
Illumination (ftc)	15
Maintenance	7
Sound	No
Visual Display	No
Access	Public

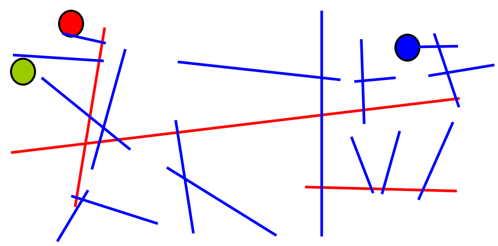
Institution	Ryerson University	Building ID	**RYMON**
Building Name	Monetary Times Building		
Address	341 Church Street		
	Toronto, Ontario		

Number of Stairs	2
Number of Elevators	1
Toronto Building Area (sf)	23821
% Stair Use	39.9 %
% Elevator Use	60.1 %

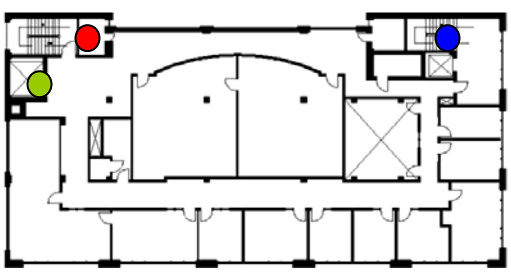
RYMONA
RYMONB
RYMONELV



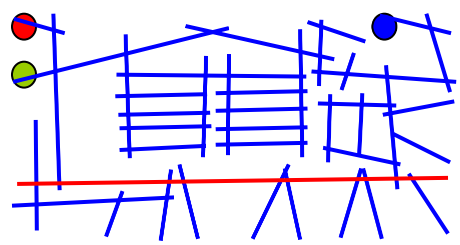
1st Floor Plan



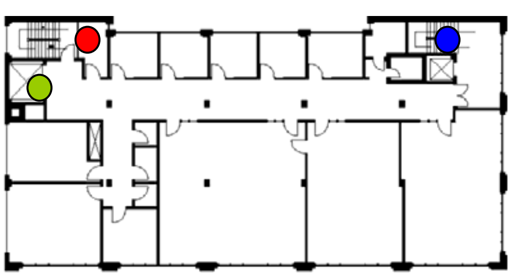
1st Floor Integration Plan



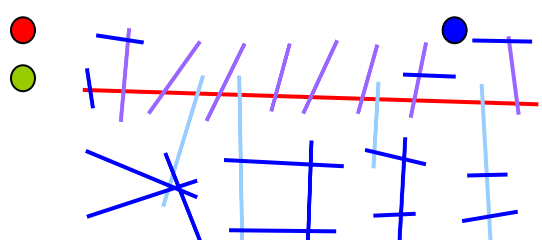
2nd Floor Plan



2nd Floor Integration Plan

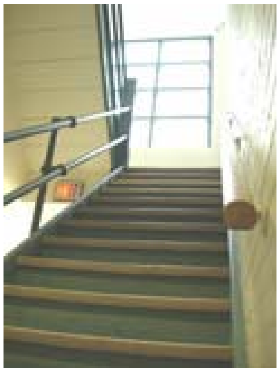


3rd & 4th Floor Plan



3rd Floor Integration Plan

Institution	Ryerson University	Stair ID	**RYMONA**
Building Name	Monetary Times Building	% of Total Building	**27.0 %**
Address	341 Church Street Toronto, Ontario	Vertical Circulation	



Stair Width (in)	36.75
Riser Height (in)	7.25
Tread Width (in)	10.25
Landing (in) Length	48
Number of Steps between Landings	14
Number of Landings between Floors	1
Floor to Floor Height	16' 8"
Handrail Height (in)	28
Guard Height (in)	33

Stair Construction	Steel with Concrete Pans
Wall Finish	Painted Brick & Drywall
Riser Finish	Painted Steel
Tread Finish	Vinyl Tile
Lighting Type	Daylight
Average Illumination (ftc)	22
Minimum Illumination (ftc)	18
Maintenance	6
View	Yes
Art	No
Access	Public
Nosing Contrast	Yes
Non-slip Treads	Yes

Effective Area (EA)		Occupant Load (OL)	
1st floor	2929 sf	1st floor	26
2nd floor	2800 sf	2nd floor	31
3rd floor	3002 sf	3rd floor	28
4th floor	3002 sf	4th floor	28
Total Effective Area	11733 sf	Total Occupant Load	113
Total EA as % of Total Building Area	49.2 %	Total OL as % of Total Building OL	36 %

Distance to Closest Entry (ft) 35

Institution	Ryerson University	Stair ID	**RYMONB**
Building Name	Monetary Times Building	% of Total Building Vertical Circulation	**12.8 %**
Address	341 Church Street Toronto, Ontario		


Stair Width (in)	44
Riser Height (in)	7.5
Tread Width (in)	10
Landing (in) Length	35
Number of Steps between Landings	12
Number of Landings between Floors	1
Floor to Floor Height	16’ 8”
Handrail Height (in)	29
Guard Height (in)	33

Stair Construction	Concrete
Wall Finish	Marble/Stucco
Riser Finish	Marble
Tread Finish	Terrazzo
Lighting Type	Daylight
Average Illumination (ftc)	33
Minimum Illumination (ftc)	10
Maintenance	7
View	Yes
Art	No
Access	Restricted Entry
Nosing Contrast	Yes
Non-slip Treads	Yes

Effective Area (EA)			Occupant Load (OL)	
1st floor	3026	sf	1st floor	36
2nd floor	3156	sf	2nd floor	41
3rd floor	2953	sf	3rd floor	62
4th floor	2953	sf	4th floor	62
Total Effective Area	12088	sf	Total Occupant Load	201
Total EA as % of Total Building Area	50.8	%	Total OL as % of Total Building OL	64.0 %

Distance to Closest Entry (ft) 116

Institution	Ryerson University	Elevator **RYMONELV**
Building Name	Monetary Times Building	% of Total Building Vertical Circulation **60.1 %**
Address	341 Church Street Toronto, Ontario	

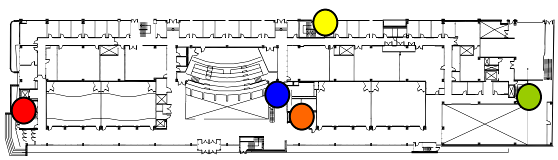
Elevator Cab Width (in)	81
Elevator Cab Depth (in	56
Elevator Cab Ceiling Height (in)	90.5
Elevator Speed (2 floor Full Trip) (sec)	20.89
Distance to Closest Entrance (ft)	21
Total Building Area (sf)	23821
Total Building Occupant Load (spaces)	314
Elevator Occupant Capacity (persons)	9

Wall Finish	Stainless Steel
Floor Finish	Vinyl Tile
Ceiling Finish	Lighting Grid
Lighting	Fluorescent
Illumination (ftc)	30
Maintenance	9
Sound	No
Visual Display	No
Access	Public

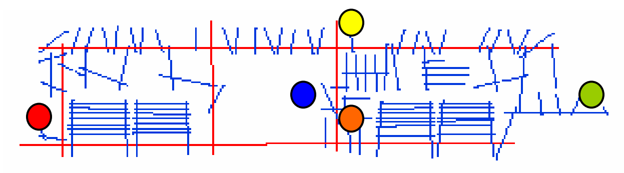
Institution	Ryerson University	Building ID	**RYENG**
Building Name	Centre for Computing and Engineering		
Address	245 Church Street Toronto, Ontario		

Number of Stairs	4
Number of Elevators	2
Toronto Building Area (sf)	173117
% Stair Use	60.0 %
% Elevator Use	40.0 %

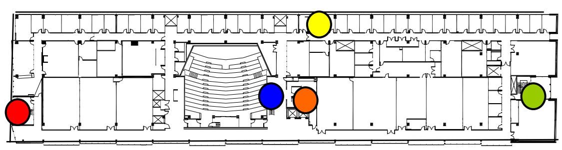
- RYENGA (red)
- RYENGB (blue)
- RYENGC (green)
- RYENGD (yellow)
- RYENGELV1 & RYENGELV2 (orange)



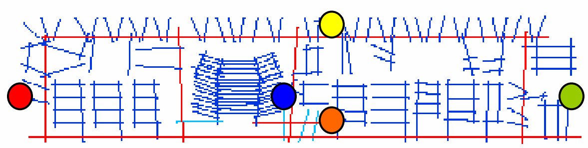
1st Floor Plan



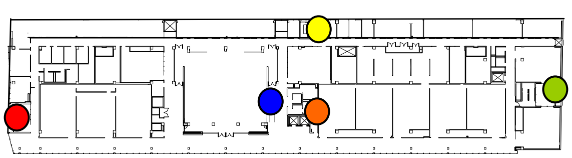
1st Floor Integration Plan



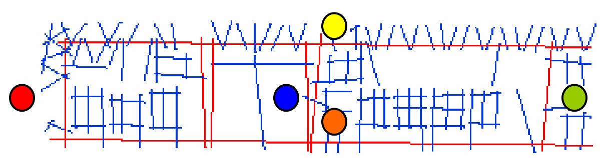
2nd Floor Plan



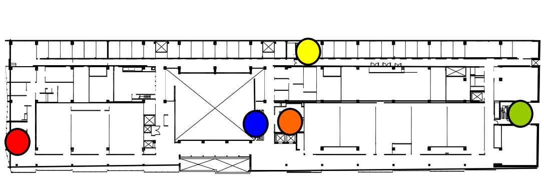
2nd Floor Integration Plan



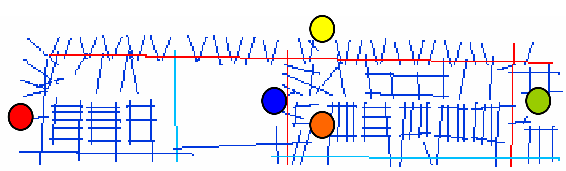
3rd Floor Plan



3rd Floor Integration Plan

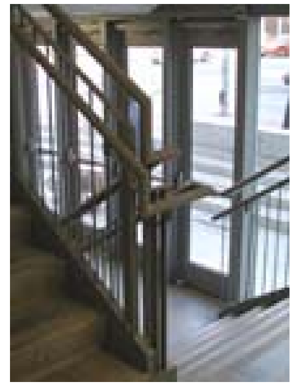


4th Floor Plan



4th Floor Integration Plan

Institution	Ryerson University	Stair ID	**RYENGA**
Building Name	Centre for Engineering & Computing	% of Total Building	**37.2 %**
Address	245 Church Street Toronto, Ontario	Vertical Circulation	

Stair Width (in)	73
Riser Height (in)	7
Tread Width (in)	11.5
Landing (in) Length	77.5
Number of Steps between Landings	5/11/11
Number of Landings between Floors	2
Floor to Floor Height	15' 8"
Handrail Height (in)	35
Guard Height (in)	42

Stair Construction	Concrete
Wall Finish	Drywall/Concrete/Glass
Riser Finish	Painted Concrete
Tread Finish	Painted Concrete
Lighting Type	Fluorescent/Daylight
Average Illumination (ftc)	30
Minimum Illumination (ftc)	25
Maintenance	8
View	Yes
Art	No
Access	Public
Nosing Contrast	Yes
Non-slip Treads	Yes

Effective Area (EA)			Occupant Load (OL)	
1st floor	11186	sf	1st floor	96
2nd floor	10970	sf	2nd floor	103
3rd floor	8096	sf	3rd floor	51
4th floor	9340	sf	4th floor	56
Total Effective Area	39592	sf	Total Occupant Load	306
Total EA as % of Total Building Area	22.9	%	Total OL as % of Total Building OL	21.4 %

Distance to Closest Entry (ft) 16

Institution	Ryerson University	Stair ID	**RYENGB**
Building Name	Centre for Engineering & Computing	% of Total Building	**20.3 %**
Address	245 Church Street Toronto, Ontario	Vertical Circulation	

Stair Width (in)	47
Riser Width (in)	6.63
Tread Width (in)	13
Landing (in) Length	48
Number of Steps between Landings	12
Number of Landings between Floors	1
Floor to Floor Height	13' 4"
Handrail Height (in)	35.75
Guard Height (in)	42

Stair Construction	Steel
Wall Finish	Drywall/Concrete/Wood
Riser Finish	Painted Steel
Tread Finish	Granite
Lighting Type	Fluorescent
Average Illumination (ftc)	19
Minimum Illumination (ftc)	12
Maintenance	9
View	No
Art	No
Access	Public
Nosing Contrast	Yes
Non-lip Treads	Yes

Effective Area (EA)			Occupant Load (OL)	
1st floor	18601	sf	1st floor	179
2nd floor	13188	sf	2nd floor	352
3rd floor	14308	sf	3rd floor	75
4th floor	11864	sf	4th floor	78
Total Effective Area	57961	sf	Total Occupant Load	684
Total EA as % of Total Building Area	33.5	%	Total OL as % of Total Building OL	47.9%

Distance to Closest Entry (ft) 69

Institution	Ryerson University	Stair ID	**RYENGC**
Building Name	Centre for Engineering & Computing	% of Total Building	**1.2 %**
Address	245 Church Street Toronto, Ontario	Vertical Circulation	

Stair Width (in)	54
Riser Height (in)	8
Tread Width (in)	10.5
Landing (in) Length	60
Number of Steps between Landings	12
Number of Landings between Floors	1
Floor to Floor Height	13’ 4”
Handrail Height (in)	36
Guard Height (in)	40

Stair Construction	Concrete
Wall Finish	Painted Concrete/Glass
Riser Finish	Poured Concrete
Tread Finish	Poured Concrete
Lighting Type	Fluorescent/Daylight
Average Illumination (ftc)	50
Minimum Illumination (ftc)	21
Maintenance	8
View	Yes
Art	No
Access	Public
Nosing Contrast	No
Non-slip Treads	Yes

Effective Area (EA)		Occupant Load (OL)	
1st floor	10431 sf	1st floor	11
2nd floor	11504 sf	2nd floor	134
3rd floor	12381 sf	3rd floor	124
4th floor	10607 sf	4th floor	69
Total Effective Area	44923 sf	Total Occupant Load	338
Total EA as % of Total Building Area	25.9 %	Total OL as % of Total Building OL	23.7 %

Distance to Closest Entry (ft) 293

Institution	Ryerson University	Stair ID	**RYENGD**
Building Name	Centre for Engineering & Computing	% of Total Building	**1.3 %**
Address	245 Church Street Toronto, Ontario	Vertical Circulation	

Stair Width (in)	61
Riser Width (in)	7
Tread Width (in)	10
Landing (in) Length	87
Number of Steps between Landings	12
Number of Landings between Floors	1
Floor to Floor Height	13’ 4”
Handrail Height (in)	36
Guard Height (in)	42

Stair Construction	Concrete
Wall Finish	Painted Concrete/Glass
Riser Finish	Poured Concrete
Tread Finish	Poured Concrete
Lighting Type	Fluorescent/Daylight
Average Illumination (ftc)	50
Minimum Illumination (ftc)	23
Maintenance	8
View	Yes
Art	No
Access	Restricted Entry
Nosing Contrast	No
Non-lip Treads	Yes

Effective Area (EA)			Occupant Load (OL)	
1st floor	NA	sf	1st floor	NA
2nd floor	10004	sf	2nd floor	31
3rd floor	10882	sf	3rd floor	41
4th floor	9755	sf	4th floor	29
Total Effective Area	30641	sf	Total Occupant Load	101
Total EA as % of Total Building Area	17.7	%	Total OL as % of Total Building OL	7.1 %

Distance to Closest Entry (ft) 179

Institution	Ryerson University	Elevator **RYENGELV1**
Building Name	**Centre for Computing & Engineering**	% of Total Vertical **22.6%**
Address	245 Church Street Toronto, Ontario	Vertical Circulation

Elevator Cab Width (in)	81
Elevator Cab Depth (in	81
Elevator Cab Ceiling Height (in)	91
Elevator Speed (2 floor Full Trip) (sec)	20.67
Distance to Closest Entrance (ft)	
Total Building Area (sf)	173117
Total Building Occupant Load (spaces)	1429
Elevator Occupant Capacity (persons)	13

Wall Finish	Plastic Laminate Panels
Floor Finish	Vinyl
Ceiling Finish	Lighting Grid
Lighting	Fluorescent
Illumination (ftc)	42
Maintenance 10	
Sound	No
Visual Display	No
Access	Public

Institution	Ryerson University	Elevator **RYENGELV2**
Building Name	**Centre for Computing & Engineering**	% of Total Building **17.4 %**
Address	245 Church Street Toronto, Ontario	Vertical Circulation

Elevator Cab Width (in)	81
Elevator Cab Depth (in	81
Elevator Cab Ceiling Height (in)	91
Elevator Speed (2 floor Full Trip) (sec)	22.37
Distance to Closest Entrance (ft)	
Total Building Area (sf)	173117
Total Building Occupant Load (spaces)	1429
Elevator Occupant Capacity (persons)	13

Wall Finish	Plastic Laminate Panels
Floor Finish	Vinyl
Ceiling Finish	Lighting Grid
Lighting	Fluorescent
Illumination (ftc)	37
Maintenance	10
Sound	No
Visual Display	No
Access	Public

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