INCUBATING FOR INTELLIGENCE: SPATIAL ATTRIBUTES AND INTERACTION EMERGENCE IN CORPORATE WORKPLACE

A Thesis

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ABSTRACT

As industries increasingly rely on innovation and knowledge workers, interaction and social networks have once again emerged as a primary purpose for working together in the place called office. The purposes of this thesis are (1) to investigate the roles of physical setting, especially on building and site scale, and its influence to foster communication and interaction in large organizations, and (2) to explore analytical tools and techniques to verify the performance of workplace spatial attributes and interaction patterns.

Employing the archival data of interaction patterns and physical data acquired from satellite images and GIS, This thesis investigates the relationship between spatial attributes and interaction emerged in four corporate campuses, including Goldman Sachs, Sprint, Sun Microsystems, and Toyota Motor Sale.

The analysis reveals that there are very low correlations for both relationships between floor plate area and interaction, and relationships between floor plate ratio and interaction. In addition, there is no predictable trend between the average travel time between building and the average interaction frequency.

There is a moderate correlation between actual travel time and self-reported or perceived travel time. The thesis also suggests that the self-reported travel time tends to be under-estimated by the employees. The actual travel time, however, has more impact on interaction in compact campuses than in dispersed campuses.

BIOGRAPHICAL SKETCH

Poonrit Kuakul is a veteran architect from Bangkok, Thailand. Since graduated with B. Arch degree from Chalalongkorn University, he had worked as a professional architect for several renounce firms, including Jones Lang LaSalle, Leigh and Orange, and Act Consultants. He was responsible for variety kinds of projects, from small residential to high rise office building.

After following his wife to the U.S., Poonrit was accepted to study for master degree in the Department of Design and Environmental Analysis, with a concentration in Facilities Planning and Management, Cornell University. After graduate, he plans to continue his career in the environmental design consulting field.

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Most importantly, love and thanks to my family for his support, especially my wife for her never-failing help. I could never have done it without them.

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Theoretical Framework and Research Initiative

“One factor that affects knowledge worker performance that isn't well understood is the physical work environment—the offices, cubicles, buildings, and mobile workplaces in which knowledge workers do their jobs. There is a good deal said about this topic, but not much known about it. Even more unfortunately, most decisions about the knowledge work environment are made without seriously considering their implications for performance.”

Davenport (2005)

Over the last decade, as industries increasingly rely on innovation and knowledge workers, interaction and social networks have once again emerged as a primary purpose for working together in the place called office (Becker, 2004; Nenonen, 2004). Interaction in the workplace is the way most employees learn the most about their discipline, their project and their organization (Brill et al., 2001). Drake (2003) finds that interaction quality in the workplace can determine the success of a business. Providing opportunities for informal learning on the job, the workplace can be a tool for bridging the gap and eliminating the barrier of knowledge networks or knowledge arbitrage in the organization.

Even though it is obvious that the physical environment of the workplace plays critical roles to enhance interaction, collaboration, and knowledge transfer (Harrison, 2006), relationships between the physical workplace and interaction patterns may not be straightforward or static, especially the relationship in large organizations. Referring to the system thinking approach, Smith (2005) identifies two major subsystems that affect performance of members in an organization. The first is external conditions, including available technology and physical environment. The second is internal environment, or the socio-technical aspect of group behavior. The internal environment involves how well people get along and how they work collaboratively together.

While much of research on human behavior in the workplaces focuses on social dynamic, relatively little attention has been paid to the role of physical environment within the organization and its relation to worker performance (Davenport, 2005; Mccoy, 2002). In addition, almost all of the studies and evaluation of the effectiveness of the workplace tend to focus more on “interior” scale, or inside the building shell, than “building” scale (Harrison et. al, 2004). This research’s main focus is to study the relations of spatial attributes of the corporate workplace and the interaction pattern that emerges. The purposes of this thesis are:

- To investigate the roles of physical setting, especially on building and site scale, and its influence to foster communication and interaction in large organizations.
- To explore analytical tools and techniques to verify the performance of the workplace’s spatial attributes and interaction patterns.

Social Interaction in the Corporation

> “…innovation – the heart of the knowledge economy – is fundamentally social. Ideas arise as much out of casual conversations as they do out of formal meetings. More precisely, as one study after another has demonstrated, the best ideas in any work place arise out of casual contacts among different groups within the same company.”
>
> Gladwell (2000)

Organizational knowledge is the most precious resource for an organization and social interaction can lead to knowledge generation and knowledge distribution. While contemporary organizations shift from being straightforward manufacturers of standard services to creative innovators, they do not only utilize a given knowledge, but also operate as original producers of knowledge. However, organizational knowledge cannot be bought in from outside nor can it be acquired readymade, but it resides in the corporate system of communication and collaboration such as the forms and modes of interaction between various knowledge workers (Schumacher, 2005).

Recent surveys from business consulting firms conclude the importance of the relation among knowledge, interaction, and innovation. From the 2006 global executive survey conducted by the consulting firm McKinsey, executives around the world consider innovation and free flow of information as the primary drivers of an accelerating competitive environment in the global business landscape. While 85 percent of the respondents (n=2,963) report that their business environment is “more competitive” (45 percent), or “much more competitive” (40 percent) than it was five years ago, the most important single factor contributing to the increasing competitive intensity in their industries is the improved capabilities of competitors, e.g. better knowledge or better talented employees (25 percent). Similar to the survey for the world’s most innovative companies, conducted by Business Week magazine and the Boston Consulting Group (McGregor, 2006), which indicates the second-biggest barrier to innovation is the lack of coordination among different teams. In addition, from a global survey by Booz Allen Hamilton, their global survey indicate only 16 percent of unhealthy companies agree that information flows freely across organizational boundaries, compared to 61 percent that agree on the same subject from healthy companies.

According to Cross & Parker (2004) and Davenport (2005), in today’s knowledge-intensive environment, knowledge workers may solve novel and complex problem at work partly by relying on their knowledge and expertise. However, it is difficult for any individual to have enough knowledge to solve increasingly complex and interdependent problems. In this case, knowledge workers may find necessary information and knowledge from impersonal source such as databases, the Internet, publications, or formal courses. The second way, which most people tend to choose, is through their social networks. Over the past twenty five years, research reports that people rely heavily on other people for finding information and learning how to get their work done.

To improve the effectiveness of their top talent, companies look for the way to create an environment that enhances social interaction and constant learning. According to the recent findings from McKinsey Consulting (Beardsley et al, 2006), what makes knowledge workers valuable is their ability to work collaboratively, to leverage relationship capital, and to improvise and improve new solutions within an environment that fosters trust and constant learning. While collaboration nurtures innovation, collaboration, however, requires more than breaking down hierarchy. The best innovator, according to the world's most innovative companies survey (McGregor, 2006), not only reroute reporting lines but also create physical space for collaboration. Innovative companies team up people from across the organization chart and build innovation culture by interaction and collaboration.

Interaction Networks

Many social networks are neither regular nor random. They are complex and lie somewhere between the extremes of order and randomness (Strogatz, 2001). Small-world network, developed by Watts and Strogatz (1998), is the mathematical model describing characteristics of real-world, large scale networks, including many natural and man-made phenomena. As its name infers, small-world network is an analogy with the small-world phenomenon, or popularly known as six degrees of separation. The distinguished coexistence properties of the small-world network are short paths and high clustering (Watt and Strogatz, 1998). Recently, researchers also applied the small-world network model in studying innovation and knowledge distribution in business firms and industries (see, for example, Cowen, 2005).

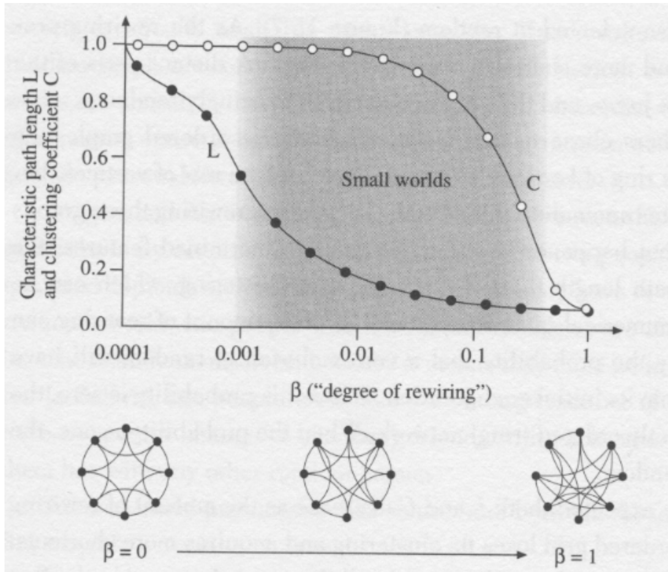


Figure 1.01 Small-world network characteristic.

Source: Ball (2004)

In the corporate context, some evidence illustrates that small-world network can be found from the interaction patterns of employees, especially from knowledge workers. Investigating social network patterns of knowledge workers in four organizations, Davenport (2005) and his colleagues find that high performers tend to have a paradoxical pattern in their networks. While they have strong relationships with a few colleagues in a well-connected network (high clustering), they also nurture diversity in their networks and have ties into physically distant locations of the organization, reaching up in the hierarchy and to those with more tenure (short path). According to the research, high performers are likely to maintain and leverage relationships and tend to have more ties reaching both outside of their departments and outside of their organizations. In addition the research also reveals that high performers are distinguished by larger and more diversified networks, which allows them to become aware of and rapidly take action on new projects or opportunities (Davenport, 2005).

On the other hand, social interaction in a company is also complex and dynamic. Stephenson (2004) argues that social networks in the workplace emerge out of trust when people work together over time, and are hidden beneath the bureaucratic organization chart or formal hierarchy. Distinguished by social roles, workers in workplaces can be categorized into three different types. The first is a “hub”, or a central node that rapidly distributes information. The second is the “gatekeeper” on critical pathways between hubs. The gatekeeper, although not connected to many, is strategically connected and serves as a bridge between parts within an organization. The last is the “pulsetaker”, or someone who is maximally connected to every one via indirect routes. In addition, there are at least six core layers of knowledge in an organization. Even though each layer has its own informal network of people interaction, everybody moves in all networks and may play different roles in each (Cleiner, 2002). Six varieties of knowledge networks are:

- The Work Network: The work network is the every day contacts to exchange information as part of your daily work routine. It represents the habitual, mundane resting pulse of organizational culture.
- The Social Network: It is the social contacts to find out what is going on in the organization. The social network is important primarily as an indicator of trust within a culture.
- The Innovation Network: This is the network of collaboration or kicking around new ideas. Key people in this network may clash with the keepers of corporate lore and expertise.
- The Expert Knowledge Network: This network is the core network whose key members hold the critical and established knowledge of the enterprise. Key people in this network are often threatened by innovation.

- The Career Guidance or Strategic Network: As its name suggests, it is networks for career guidance and mentoring. It indicates a high level of trust in itself and often influences corporate strategy move because both are focused on the future.
- The Learning Network: It is the network for improving existing processes or methods. Key people in this network may be a bridge between hubs in the expert and innovation networks.

Based on these ideas, Stephenson has developed a procedure to diagnose and identify social networks in an organization. She works regularly with a handful of clients each year. Most of them are business organizations, preferring the firms that are facing a turning point such as merging or acquisition. Collaborating with selected architect and design firms, Stephenson helps the firms to map out workplace planning that can enhance interaction, establish trust among the workers, and retain top talents with the companies (Cleiner, 2002; Watters, 2006).

By the advancement of technologies, business organizations see benefit in mapping or visualizing the interaction networks and using the network analysis approach to study the collaborations and communication patterns that cannot be illustrated by the formal organizational diagram.

While Davenport’s findings are consistent with small-world networks properties, interaction networks in the workplace require more studies to understand their characteristics. Since it is obvious that the physical workplace influentially participates in shaping the behaviors of workers, studying relationships of interaction networks and physical settings will create better understanding of social networks in an organization.

Relation of Interaction and Physical Setting

By definition, an office is a physical place with features and properties that provide both functional opportunities and multiple levels of meaningful interaction and feedback for the people who work in it (Mccoy 2002). From this perspective, physical space creates values in terms of providing a necessary setting for employee's activities and interactions. Built environments, such as a building, are organized in functional layers, and an upper layer set constraints for the next level down. For example, geographical characteristics, as an upper layer, have impacts on smaller scales such as shape or orientation of the building, which in turn set a context for lower layers such as heating and lighting systems within the building (Leaman, 2006).

Hatch (1997) develops conceptual a model explaining relationships of physical setting and organizational issues. From her approach, while social relationships define its social structure, organizational physical structure is defined by the relation of physical elements. According to her model, organizational physical structure is structured in three layers and each layer involves different particular organizational issues.

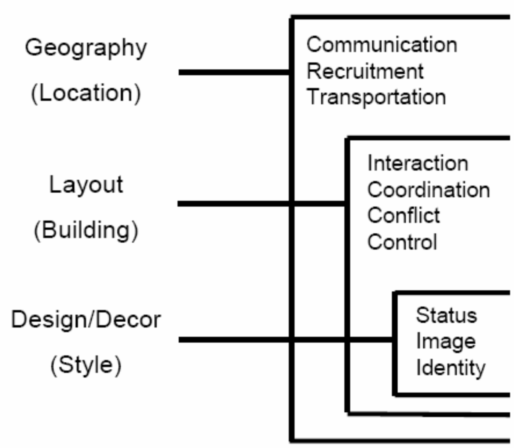


Figure 1.02 Hatch's conceptual model of the interrelation.

Source: Hatch (1997)

The model includes that interactions in an organization tend to relate to the intermediate physical layer called layout, or buildings. Layout refers to the spatial arrangement of physical objects and human activities. In addition, layout involved both spatial arrangements within a specific building and between buildings in a specific location. While within a building, layout involves the internal placements of objects that carve up and define interior spaces. For a location that has more than one building, layout will refer to orientation of the buildings to each other (Hatch, 1997).

Nicolaou (2006) argues that, in the contemporary workplace, the network of personnel knowledge and the exchange of information expand beyond the boundary of organizations and day-to-day interaction. The convergence of computing and communications technologies makes the networks becoming increasingly virtual. However, the processing of information into knowledge is more effectively support by face-to-face interaction. The exchange, both formal and informal, takes place in variety of settings, for example semi-public spaces, shared space within the building, socialized spaces outside the building or within urban events spaces. In supporting knowledge generation, spaces between buildings are as important as spaces within buildings.

Linking spatial dimension with organizational theory, Kornberger and Clegg (2004) argue organization should be thought of as material, spatial assemblies. Organizational physical settings, such as a building, should contribute positively toward an organization’s capacities. In their proposal, they introduce the concept of generative building, or spatial arrangement that organizes the flow of communication, knowledge, and movement instead of being a passive container for actions or operations of the organization. Specific aspects of generative building is directly involved with providing a physical setting that invites its inhabitants to participate and redefine their context for creating sustainable organizational development. For example, an organization can create flexibility by providing loosely coupled space, or can combine order and chaos to create ambiguous, incomplete space that helps collaboration and creativity emerge from the bottom up (Kistensen 2004).

The implication of physical places to an organization was also identified by Nicolaou (2006). According to her report, the new workplace building settings are concerned primarily with informal contact encouragement or social contact that can stimulate the generation of idea. Physical places, in summary, are important for:

- Communicating culture, or communicating what the organization stands for;
- Facilitating and increasing the effectiveness of face-to-face interaction;
- Creating trust among co-workers or collaborators;
- Fostering relationships and generating the context for casual creative contact (Nicolaou, 2006).

In contemporary practice, it is frequently found that business organizations have employed several techniques to create their physical setting to improve social capital, innovation, and production. Some organizations have begun to model their meeting spaces on traditional communal spaces from outside the corporate world by applying city planning or urban typology approaches such as the main streets, town squares, and neighborhoods of traditional communities. These environments promote walking and talking. In organizations, the public spaces where people see and are seen by each other generate energy, connection and sense of belonging (Cohen and Prusak, 2001; Gillen, 2006). Even though there are several strategies that companies can implement in their internal environment, organization may, in summary, combine or use one of the following approaches to promote more interaction in their workplace:

- *Dedicated Function Approach*: Organizations provide dedicated facilities and use their functional premises to promote interaction and purpose, both formal and informal. Most of the general facilities found may be conference rooms, canteen, project rooms, or even a bench in the office corridor. These facilities can be permanent facilities or temporary, flexible areas that organizations provide for just in time interaction. In addition, decoration and information design can be used to attract or magnet interaction.

- *Strategic Location Approach*: Some locations have, naturally, high potential for boosting interaction among people. For example, the crossroads at which people naturally meet, or a transition area such as a staircase, corridor, or lobby hall. Companies can use these high potential areas to generate more informal interactions. On the other hand, the strategic location approach includes the way organizations locate or distribute their spatial organization to stimulate interaction. It can be a positive approach such as the use of proximity to promote chance encounters, or a negative approach such as the use of functional inconvenience in order to force people to walk more along strategic paths. Such that, they can have more chance to meet each other informally.

Spatial Attributes in the Corporation

"…space is the material support of time-sharing social practice."

Castells (2000)

Space is a complex subject and there are various approaches to study or categorize it, mostly depending on the researcher's discipline. From the perspective of the field of organization psychology, organizations are one big conglomerate of physical artifacts, including, for example, buildings, office, colors, dress and accessories, furnishings, or logo and emblems (Vilnai-Yavetz and Rafaeli, 2006). In their recent analyses (Rafaeli and Vilnai-Yavetz, 2004; Vilnai-Yavetz et al, 2005), physical artifacts can be categorized into three dimensions: instrumentality, aesthetics, and symbolism. The first dimension, instrumentality, refers to the extent to which the artifact contributes or hampers performance of individual or organizational related tasks and desired goal.

This dimension is generally suggested in analyses of usability and human factors engineering and evaluations of physical places according to goal attainment. The second dimension is aesthetics. Suggested by research and practice of space and environmental design, aesthetics is the sensory reaction to the artifact. Symbolism, the third dimension, regards associations the artifact elicits. These three dimensions conceptually dissociate to each other, however, both experts and nonexperts recognized the three dimensions (Vilnai-Yavetz and Rafaeli, 2006). From their recent report, it was confirmed both qualitatively and quantitatively that people recognize three separate dimensions. Instrumentality was found to be related to employee satisfaction and effectiveness. Aesthetics was related only to satisfaction, and symbolism was not related to satisfaction or effectiveness. In addition, the resulting artifact errors, or artifact myopia, are critical to organizations' performance. The failing to recognize the full complexity of artifacts can dampen financial success of organizations.

Reviewing recent literature on the work environment, McCoy (2002) has found that it involved several disciplinary and methodological approaches as well as various ontological priorities to understand human experiences, processes, and behaviors. Her study has also organized the theme around the physical attributes of the workplace. Her categories include spatial organization, architectonic details, views, resources, and ambience properties. This thesis, however, focuses on only some of the spatial attributes that affect interaction patterns in business organizations. This study of spatial attributes is limited to spatial distribution, and configurations.

Spatial Distribution

Integrating with information technologies, distributed workplaces in the age of the knowledge economy transform to be hybrid workplaces consisting of physical and virtual space. As virtuality and dispersal increase, organizations become more concerned about where and how they should locate buildings. The old model of an office building as a command and control structure is replaced by the office as a way of bringing people together (Gillen, 2006). According to Harrison et. al (2004), the development of distributed and hybrid workspaces enable organizations to configure their use of physical space at a fundamental level. And many large organizations have to face apparently conflicting pressures of whether to centralize or disperse their physical workspace.

Resource allocation strategies for each corporation are different from firm to firm. Even in the same company, strategies also vary from location to location, and from time to time. For a large corporation, it is impossible to locate everything within the same floor or even the same building for optimal collaboration. The corporate workplace mostly occupies space from several floors within a building to several buildings. The corporate campus, according to a loose definition given by the International Workplace Study Program (IWSP), Cornell University, is a group of multiple buildings located within walking distance of each other. Assumed benefits of the aggregate workplace include providing better collaboration and strengthening trust and the sense of community of employees by keeping everyone together in physical contiguity (Andrew et. al, 2005; Becker et. al, 2003).

Very few studies exist for studying the topology and relation of groups of buildings combined into a corporate workspace. The IWSP research team developed a corporate campus typology employing binary principles based on (1) architectural image of the building, (2) real estate strategy, and (3) location. An other way of categorizing the corporate campus comes from the architectural firm DEGW. Based on their professional expertise, (see Andrew et. al, 2005), and is mainly based on the spatial characteristics and location of the campus. In addition, DEGW also suggests that campuses can work at two different scales. The first level is local teams that have a strong need for interaction. The second is the whole business scale, which includes the ability to share the amenities of clumps of local teams. Clumps can be arranged in many ways.

Recent findings from IWSP's corporate campus research imply that collocation is unlikely to enhance the level of face-to-face interaction beyond one's own group, or beyond one's own floor. The results also suggest that corporations prioritize the collocation of an entire department on the same floor. Even though it does not increase interaction within a team, it can lead to a stronger sense of belonging. For interaction across buildings, the report also indicates some influences from spatial distribution characteristics. In the campus that has most tightly clustered buildings, people tend to give higher value, in comparison, for interaction than those in the other two campuses that have more dispersed groups of buildings.

While IWSP's works lay a solid ground for studying the effect of spatial distribution in corporate workplace in general, this study focuses on a couple of variables attributed from spatial distribution strategies: (1) physical distance, and (2) travel time that employees spend getting to interactions.

Physical Distance

Distance has been seen as one of primary constraints for interactions among people. In the field of spatial economics, the spatial interaction model is used for studying the processes by which entities in different physical space make contact decision or locational choices. The entities can be individuals or firms and the choices can be housing, jobs, activity center, or face-to-face contact (Roy, 2004; Roy and Thill, 2003). The very first pioneer concept of the spatial interaction model can be grouped under generic name gravity model, which is expressed as a general form shown below:

$$Fij \sim kMiMj\ (Dij)^{-2}$$

Where F is the interaction between region i and j, k is a constant, Mi and Mj are properties of region i and j respectively, and Dij is the distance between region i and j.

Like the macro scale of interactions, in the work environment context, physical distance has also been seen as a constraint for face-to-face interaction and collaboration in an organization. Since the late 1970, Allen (1977; 1997) has studied patterns of communication in the collaborative workplace. The results consistently found, also known as Allen Curve, revealed a distinct correlation between distance and frequency of communication. In other words, the more distance there was between people, the less they would communicate. In addition, even a modest separation between people in the same building has a profound effect on their interaction patterns. According to his studies communication probability declines to an asymptotic level within the first 50 meters of separation and there is a modest drop in probability after the first 50 meters (Allen, 1997).

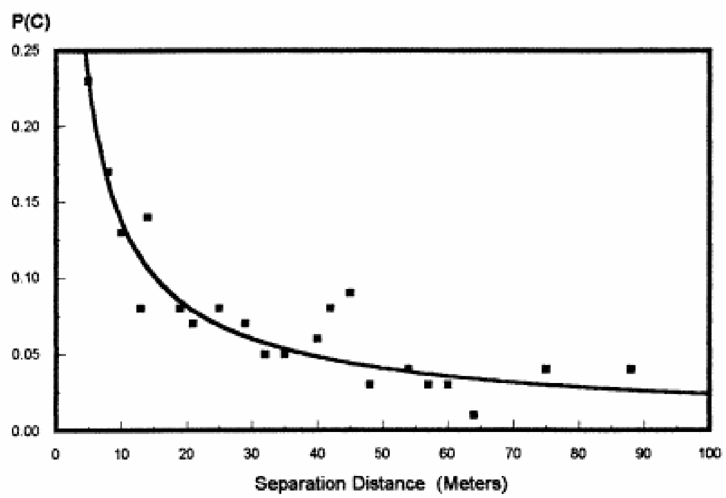


Figure 1.03 Allen Curve.

Source: Allen (1997)

A recent corporate campus study series from IWSP also reveal similar patterns. The frequencies of interactions decline dramatically beyond one's own floor and after that point, there was no significant difference for interaction declining when physical distances increase, except where there is a strong functional relationship (Becker et. al, 2003). The study sites of the research include four corporations in North America and two companies in South Korea and Taiwan. The findings indicate that this relation permeates across different types of corporate campus in widely different localities.

Travel Time

Similar to physical distance, travel time is seen as a constraint for an interaction. However, there are very few studies that investigate the effect of travel time on communication patterns in the work environment. On the contrary, travel time is one of the critical variables in more macro scope, such as urban planning, transportation, or urban/regional economics. In large scale space planning, for example an educational campus, appropriated average travel time from a building to any other building in the campus is carefully considered, so that students and faculties would have enough transition period for travel from class to class. In a business organization context, as well as physical distance, most of quantitative studies that model the travel time involved can be found in logistic and supply chain management.

For a large organization's workplace that includes more than one building, travel time seems to be a less important consideration compared to other issues such as cost of acquisition or exit strategies. Especially, in the age of advance communication technologies, the IT system is frequency, and arguably, considered a substitute for face-to-face interaction.

From the New Urbanism approach, the optimal size of a neighborhood is a quarter mile from center to edge, which is equivalent to five-minute walk (Becker, 2004). This five-minute rule reflects some psychological radius for unplanned, face-to-face interactions in a community. For a corporate campus or large-scale workplace, there is no consensus for travel time that can optimize interactions, even though the term corporate campus, according to IWSP's definition, refers to a group of buildings within roughly 15-20 minutes of walking. In the IWSP's corporate campus study report, findings from comparison of 3 different corporate campuses reveals that the frequency of interaction decline significantly after 3-4.5 minutes of travel time. However, some exceptions occur when there is the strong tie of a necessary functional relation (Becker et. al, 2003)

Often considered as a correlation with physical distance, travel time can be seen as more complex since it involves both the objective and subjective. In addition, subjective travel time, or the travel time people perceive, can be a critical factor for the decision whether it is worth to have face-to-face interaction or not. While some studies have investigated the effect of travel time on interaction patterns, the relationship of subjective travel time and objective travel time is still unexplored in the corporate workplace context.

Configuration

Configuration of the physical environment can be seen from different perspectives, such as shape and form of the building, orientation, or deep structure of spatial organization. Allen (1997) mentions the ideal form of the building that can optimize interaction and communication is the circle form, since the shape minimizes separation distances in the plan. A more conventional solution, however, is a square. Linear form should be avoided because they maximize the average separation distance (Allen, 1997).

To study and identify the underlying structures of space that are linked to observable patterns of behavior, or social functions, of the people that occupy the space, space syntax is one of techniques that can explore these relations. Space syntax is best described as a research program that investigates the relationship between human societies and space from the perspective of a general theory of the structure of inhabited space in all its diverse forms: buildings, settlements, cities, or even landscapes. According to space syntax literature, space syntax theory denies the simplification of space-as-form and society-as-content distinction. The aim of space syntax research is to develop strategies of description for inhabited spaces in such a way that their underlying social logic can be enunciated (Bafna, 2003).

Developed by Professor Bill Hillier and a group of researchers from University College London in the mid 1980s, the departure point of space syntax is turning continuous space into a connected set of discrete units (Bafna, 2003). Space syntax analysis consists of three primary components, including convex map, axial line and integration. Based on graph theory, the main methodology of space syntax is to reduce any configured space into an appropriate graph. With this process, any spatial configuration is mapped by a boundary partition and is called the convex space partitioning or convex map. According to Hillier & Hanson (1984), the procedure of generating the convex map involves taking a given spatial setting and partitioning it into a set of “fewest and fattest” convex spaces. Based on this set, a graph can be constructed by identifying each convex space with a node and each accessible connection between the convex spaces with an edge.

As space syntax literature claims, one of the important concerns of space syntax studies is to describe the dynamism of social life in spaces. This purpose can be achieved by overlaying another discrete map on the top of a convex map to capture the structure of movement within a setting through the alignments of its constituent convex spaces. The map is called linear map or axial map (Bafna, 2003). The procedure to generate an axial map is to lay down “the longest straight line” that passes through at least one permeatable threshold between two adjacent convex spaces and repeats this until all permeatable thresholds between two adjacent convex spaces have been crossed. The resulting network is the axial map and it can also be represented as a graph in which each line is represented by a node and each intersection as an edge (Bafna, 2003).

To analyze the behavioral characteristics of spatial settings, the "integration" or "real relative asymmetry" (RRA) was measured. Integration is a ratio computed by calculating the average depth of each node from all other nodes in the graph. Generally, higher integration values of nodes indicate that the node is less deep on an average from all other nodes, or more integrated into the spatial system. According to space syntax literature, there is a very noticeable correlation between integration values of a node and average number of people found in the space (Bafna, 2003).

Research Questions

The research questions include:

1. How do spatial attributes of corporate workplace relate to interaction patterns?
    - Does frequency of interaction, both interaction within each building and interaction between buildings in the same campus differ from each other?
    - What are the main characteristics of spatial distribution, including cluster, physical distance, and travel time of each campus?
    - In each campus, are there any relations, or predictable trends, between (1) frequency of interaction and floor plate area, (2) frequency of interaction and floor plate's compactness, and (3) frequency of between-building interaction in any building and locational factor of the building?

2. What is the difference between actual travel time, based on physical setting analysis, and perceived, or self-reported, travel time in the workplace?

    - Do the actual travel time and the self-reported travel time correlate?
    - Are there any predictable trends between actual travel time and between-building interactions?

Chapter 2

Data, Methodology, and Tools

Focusing on the relation of physical attributes and interaction patterns in a corporate context, this research partly reutilizes the archival dataset from IWSP's corporate campus survey from 2001-2003. The main reason to use the archival data is it is a huge collection covering self-reported opinions of the respondents from large-scale corporations regarding travel time and interaction of various types. Additional data about physical attributes of each site are collected and are investigated beyond the original IWSP studies. In addition, different analysis tools also employed to make comparative studies of interest variables across different corporate sites.

Study Sites

In the corporate campus studies from 2001 to 2003, IWSP selected four corporate campus sites in the United States from different companies in different locations. They were Goldman Sachs, Sprint, Sun Microsystems, and Toyota Motor Sales Inc. While all the organizations selected operated in a service sector, their physical workplaces' characteristics and their spatial attributes were different. General characteristics of the study sites are illustrated on the next page:

Exhibit 2.01 Comparative characteristic of study sites.

	Goldman Sachs	Sprint	Sun Microsystems	Toyota Motor Sale
Location	New York City, NY	Overland Park, KS	Bloomfield, CO	Torrance, CA
Total Area (Sq. M.)	339,483	371,600	102,190	150,194
Population	11,417 employees and 900 consultants	13,500	2,800 employees 700 consultants & vendors	4,400 (1,600 off-campus)
Amount of Buildings	8	16	7	15 (4 off-campus)
Building Type	High-rise, speculative office towers	Custom design, low-rise buildings	Custom design, low-rise buildings	Low-rise building, mostly acquire speculative space.
Major Departments	Asset Management Technology Fixed Income Equities Investment banking Operations & administration HR Support Investments Research	Fixed-line Telecom Services Digital Wireless Network	Services Global Sales Storages Software IT Finances CRE HR	Planning & Administration Executive Offices Customer Services Corporate Communications Financial Services Brand Divisions

Goldman Sachs

Goldman Sachs (GS) is a financial service company and its New York campus was located in the financial district of New York City at the time of IWSP's survey period in 2002. IWSP categorized the campus as an "Architecturally Non-Branded, Ad Hoc, Urban campus". The GS campus in New York City was distributed in 8 buildings in 2002. The acquisition strategy was one by one as required and surrounded the headquarters building. Since all the buildings were speculative properties, there was no identity associated with the brand of GS.

Figure 2.01 Location of Goldman Sachs Corporate Campus

Sprint

Sprint Corporation, now known as Sprint-Nextel after merging in 2005, was a holding company for two operational units, including telecommunication services and wireless network services. Completed in the fall 2002, Sprints World Headquarters Campus is located in Overland Park, on the outskirts of Kansas City.

On a 200-acre site, the campus accommodated about 12,000 staff at the time of the survey (2003) in 17 office buildings. In addition, a fitness center building and a central services building was included. The total GSF was 400 million. Other amenities were retail, dining centers, meeting space, auditorium, and outdoor recreation space. The Sprint World Headquarters Campus was categorized as an architecturally branded, purpose-built, suburban campus.

Figure 2.02 Location of Sprint Corporate Campus

Sun Microsystems Inc.

Sun Microsystems (Sun), a leading computer technology company, has a campus located outside Denver, Colorado. Like Sprint World Headquarters Campus, Sun's campus is an architecturally branded, purpose-built, suburban campus. However, the Sun campus is smaller. There are 7 buildings on the campus with 1,100,000 GSF, accommodating 2,800 employees and 700 consultants and venders at the time of the survey.

Figure 2.03 Location of Sun Microsystems Corporate Campus

Toyota Motor Sales USA Inc.

The headquarters campus of Toyota Motor Sales USA Inc (TMS) is located in Torrance, CA, which is an industrial/commercial area in the suburbs of Los Angeles. At the time of the survey study, there were 12 buildings on the campus that accommodated about 4,400 employees. In addition, there were another 400 staff in four off-campus locations within a 20-mile radius. The off-campus buildings are (1) Toyota Plaza, (2) Hamilton Building, (3) Torrance Center, and (4) Toyota Project Center. The TMS campus was an architecturally non-branded, ad hoc, suburban campus according to IWSP’s category system.

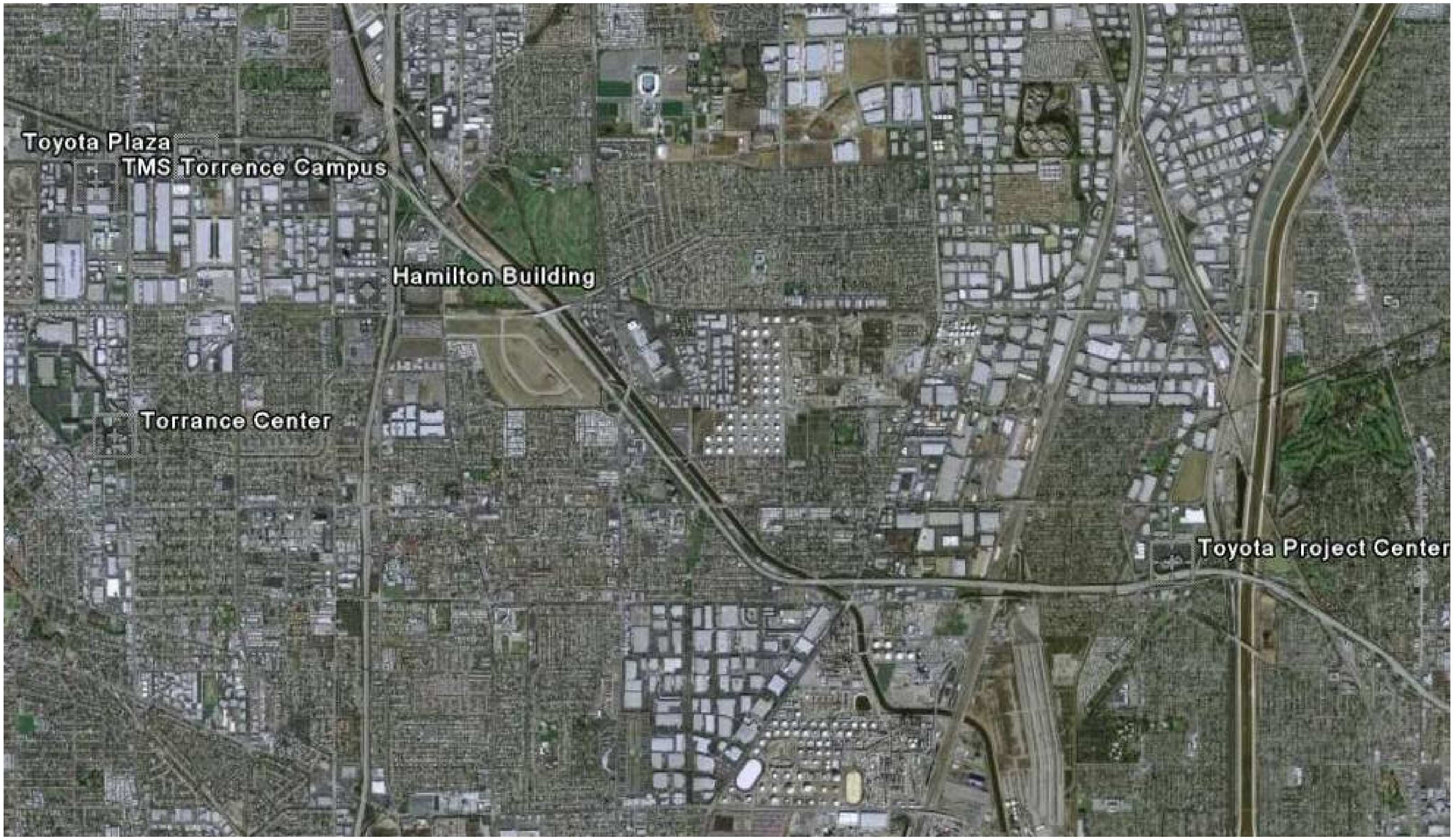


Figure 2.04 Location of Toyota Motor Sale Corporate Campus

Figure 2.04 (Continued)

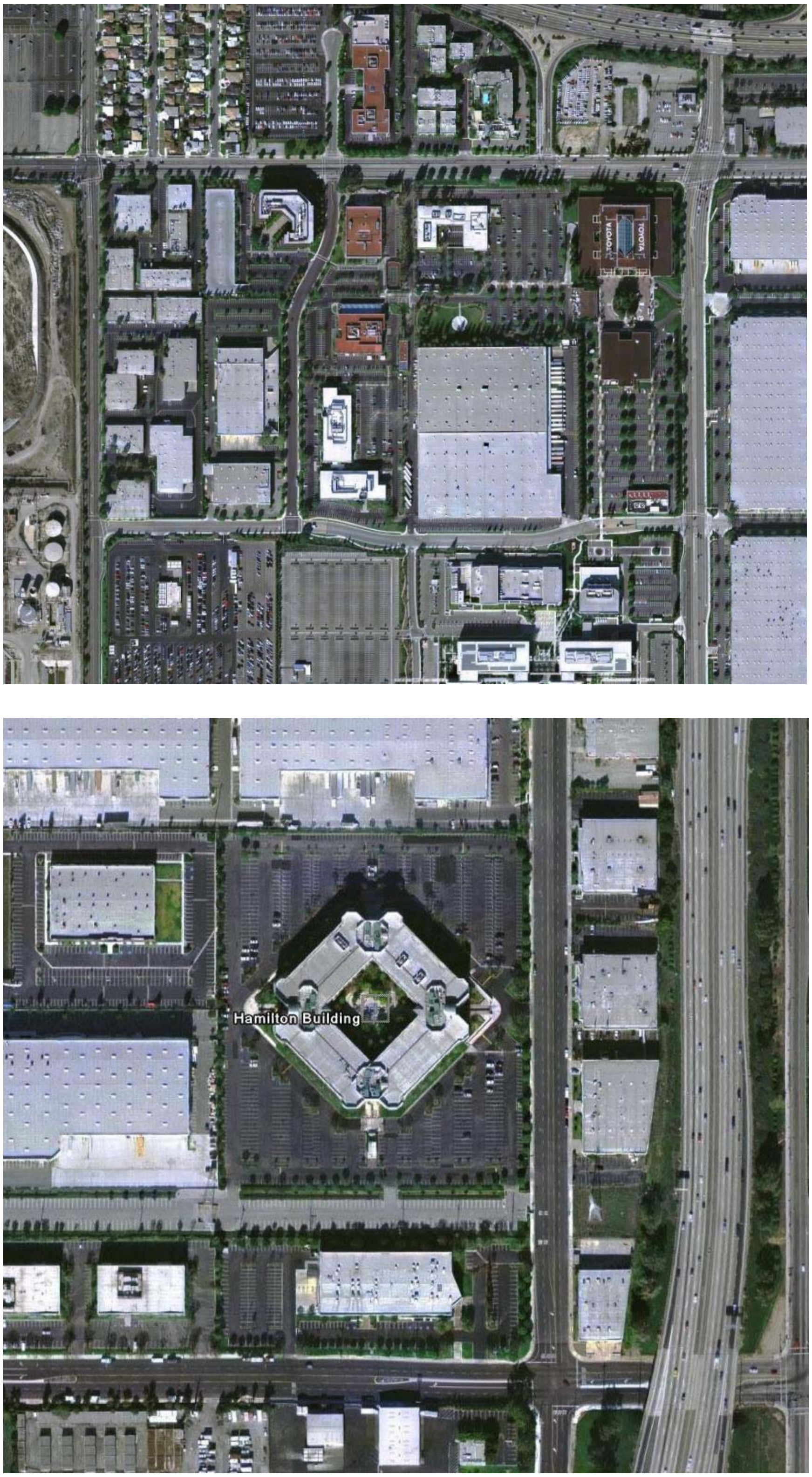
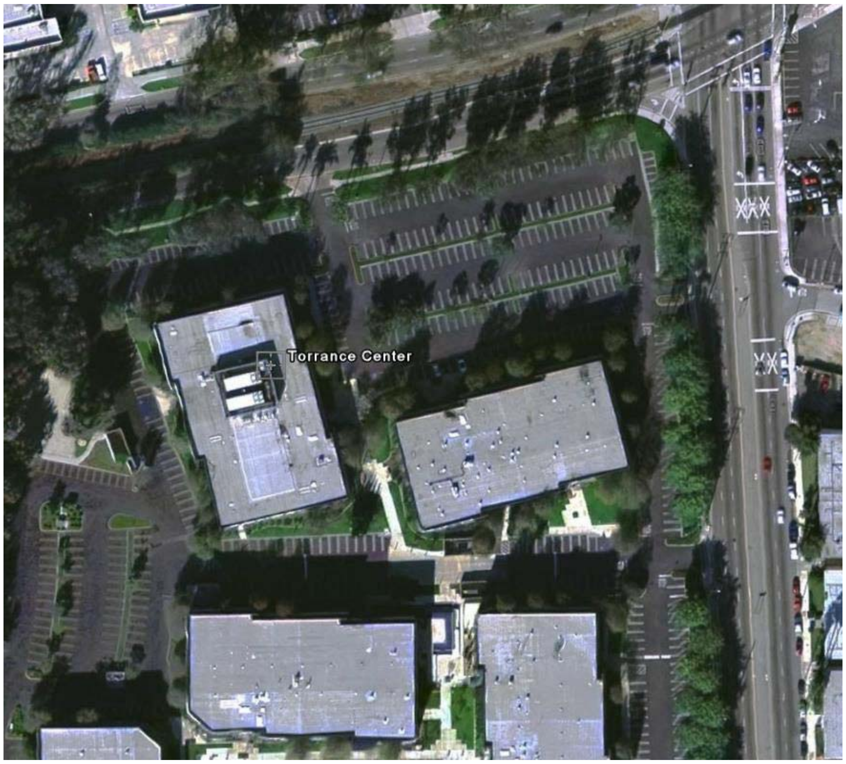
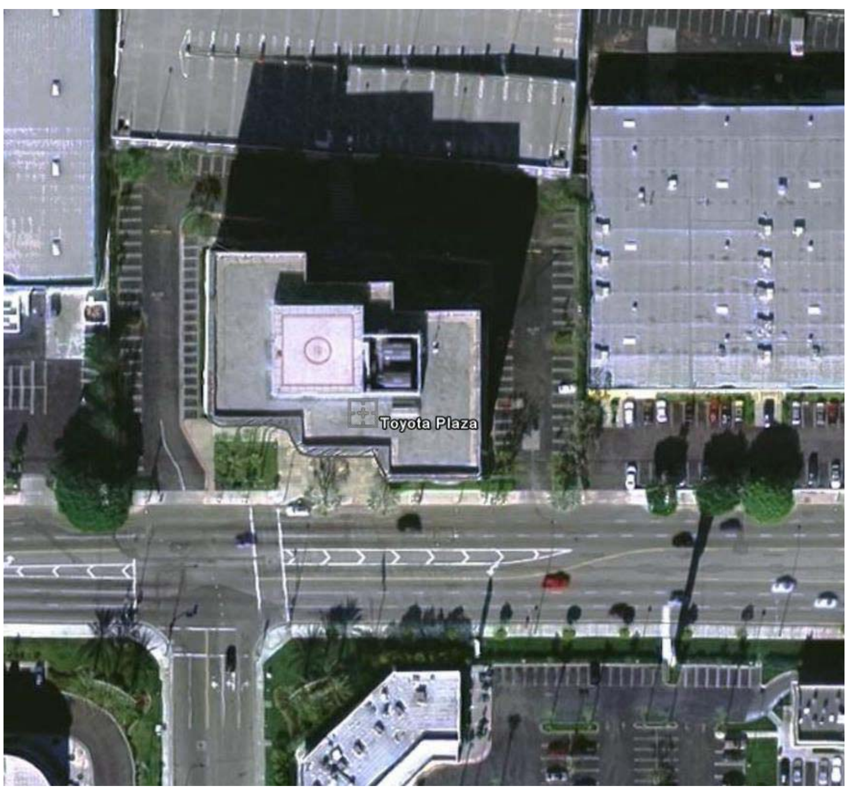


Figure 2.04 (Continued)





Data Acquisition and Data Selection

The archival data set from the IWSP survey was collected using a web-based survey and PocketDiary©. The web-based survey was compiled and coded by Cornell University's Computer Assisted Survey Team (CAST). Anonymity for respondents was provided. To complement the web-based survey, the PocketDiary© survey was aimed to collect interaction behaviors in real time. In summary, there were 774, 3,120, 771, and 418 response from the GS, Sprint, Sun, and TMS respectively. Even though the PocketDiary© survey was conducted for GS, Sprint, and Sun, for this research, only information from the web-based survey is used.

Even though there were respondents from almost all of the buildings in the study sites, to make the statistical analysis more valid, the buildings that had the less than 30 respondents were dropped from the study, as well as the data from the respondents that were unable to locate the building they were working in. Exhibit 2.05 below illustrates the number and percentage of respondents according to their building from each study site.

- Goldman Sachs

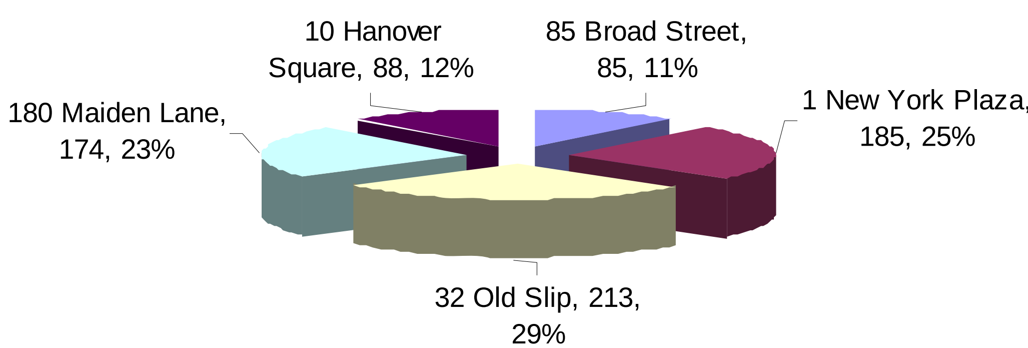
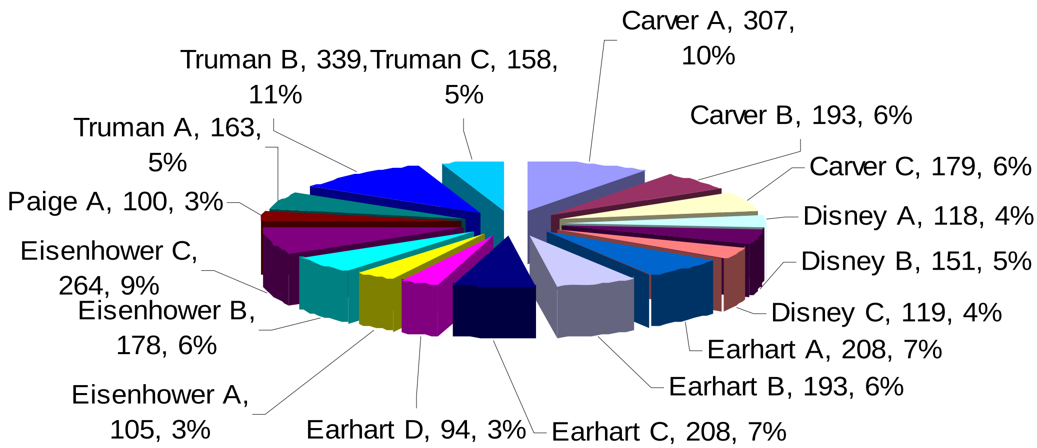


Figure 2.05 Number of the respondents in each building.

Figure 2.05 (Continued)

- Sprint



- Sun Microsystems

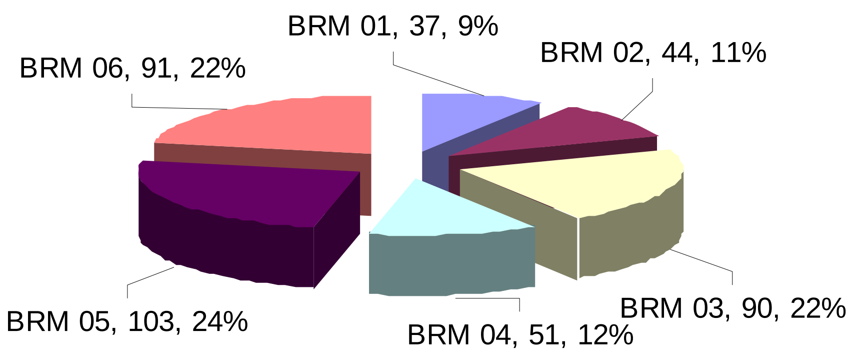
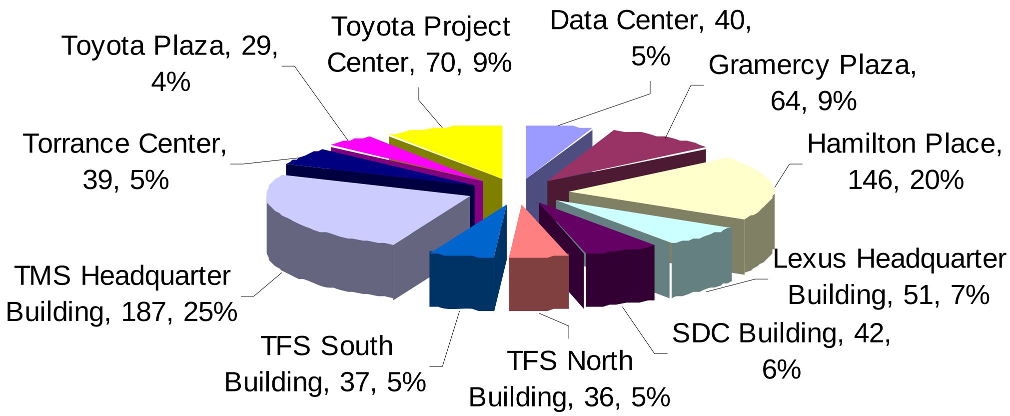


Figure 2.05 (Continued)

- Toyota Motor Sales



In addition, only questionnaires associated with interaction patterns and the physical characteristics of their workplaces are selected for analysis in this research. Exhibit 2.02 below summarized the main characteristic of the selected respondents, and Exhibit 2.03 summarized details of the selected questions.

Exhibit 2.02 Characteristic of the selected respondents.

		GS	Sprint	Sun	TMS
Selected Respondent	Total Selected Respondent	745	3,001	416	741
	Percentage of Respondent	6%	25%	12%	12%
Gender	Male	457	1,358	209	353
	Female	285	1,643	195	365
	Refused	3	76	14	23
Age	Less than 25	108	133	15	33
	26-35	367	1047	144	203
	36-45	200	1021	146	266
	46-55	62	674	84	171
	More than 56	6	134	17	38
	Refused	2	68	10	30
Job Level [1]	Individual Contributor [2]	129	1,977	223	451
	Supervisor/Middle Management [3]	322	944	141	163
	Senior Management [4]	292	96	35	108
	Refused	2	60	17	19
Tenure with the Company [1]	Short Term [5]	79	95	29	53
	Short/Medium Term [6]	446	884	203	159
	Medium/Long Term [7]	112	1,242	156	233
	Long Term [8]	95	798	22	278
	Refused	3	58	6	18

Notes

[1] The rank of this category is modified by the researcher for comparison propose
[2] Individual Contributor for each site includes:
GS: Admin/Non-exempt and Temp/Consultant
Sprint: Individual Contributor
Sun: N/S Grades (Admin) and E2-E9 (Professional)
TMS: Administration, Analyst, Professional
[3] Supervisor/Middle management for each site includes:
GS: Associate/Analyst/Exempt
Sprint: Supervisor and Manager
Sun: E10-E12 (Middle Management)
TMS: Staff Manager
[4] Senior Management for each site includes:
GS: MD and VP
Sprint: Director and Vice President
Sun: Z Grades and Dir/VP
TMS: National Manager, Corporate Manager, Vice President,
Group Vice President, Senior Vice President, and President
[5] Less than 1 year
[6] 1-3 years for GS, 1-4 years for Sprint, Sun, and TMS
[7] 4-10 years for GS, 5-10 years for Sprint, Sun, and TMS
[8] More than 10 years

Exhibit 2.03 Selected questions from archival survey.

Measurement	Question	Scale
Frequency of Interactions	Face-to-face meeting with people at the company in typical week: • On the same floor • On different floor of the same building • In a different building in the campus (specify the building)	Five- level scale: • 0 times/wk • 1-5 times/wk • 6-10 times/wk • 11-20 times/wk • 21+ times/wk
Location of Respondents	Specify the location of the respondent's office.	Specify the building and floor the in which respondent's office locates
Travel time	Quantity of time the respondent spends in each typical week getting to and from meeting in the campus building other than his/her own building.	Six- level scale: Less than 15 minutes 15-30 minutes 31-60 minutes 61-90 minutes 91-120 minutes 120+ minutes

For spatial attributes data, aerial photographs of each site were obtained. The earth imagery and geographic information software, Google Earth, were used to measure physical dimensions, including each building's floor plate area and the distance according to walking route between the buildings. In addition, the Google Earth's aerial photograph of each campus, except Goldman Sachs, was also used as a base image for space syntax analysis. The GIS tax blocks map of the New York City generated by New York City Department of City Planning (http://www.nyc.gov/html/dcp/html/bytes/dwnblk.shtml) is used a base map for space syntax analysis of Goldman Sachs because it can present clearer street routes that are necessary to generate the axial line. The physical data for this study are:

Travel Distance: Travel distance for an employee's travel to meeting is calculated, in metric scale, by measurement of physical distance from the building the employee occupies to the building of meeting location.

Actual Travel Time: Similar to travel distance, travel time for each employer's travel to a meeting is calculated as follows:

Travel time within the building (horizontal + vertical) + Travel time from his/her own building to the destination building.

In order to calculate actual travel time, the following assumptions are made:

Walking speed = 0.9 meter per second (2.01 mph)

Driving speed = 35 kilometers per hour (21.75 mph)

For each study site, the below exhibit is summarized the assumptions used for the calculation.

Exhibit 2.04 Travel time calculation.

Site	Travel Time Calculation		
	Inside Building	Outside Building	Other Factors
GS	3.5 Min.	Distance Between Building divided by walking speed	Plus 10% of the travel time outside building due to the possibly waiting time crossing streets.
Sprint	2 Min.	Distance Between Building divided by walking speed	-
Sun	2 Min.	Distance Between Building divided by walking speed	-
TMS	2 Min.	Distance Between Building divided by walking speed or driving speed	In the case of driving, plus 3 minutes for the time spent going to, or going from, parking lot.

Floor Plate Area: Typical floor plate area of each building is calculated in metric scale using Google Earth Pro software.

Floor Plate Compactness Ratio: The length and the depth of the typical floor plate are calculated in metric scale, using Google Earth Pro.

Axial Map: Using syntax analysis methodology, the integration of each site is calculated to verify the possibility of unplanned interaction chance for each campus. The axial map for each study site is generated to identify the area that enhances interactions in the campus.

Analysis Methodology and Tools

The data is crosstabulated against the location (building) factor. Then, to analyze the relation of spatial distribution and interaction pattern, the statistical methods applied include mean comparison within and among the four study sites. Correlation and linear regression is also employed to verify the trends of relationships. The tools used for statistical analysis are SPSS and MS Excel. As mentioned earlier, Google Earth is used to measure physical dimensions of buildings and sites. For space syntax analysis, Webmap 1.0 is used to compute space syntax properties and to generate axial maps.

Chapter 3

Research Findings

The results of the analysis in this chapter include (1) the summary of the interaction patterns found in each study site, (2) spatial attributes and main characteristics of spatial distributions in each campus, (3) relations of the interaction patterns and spatial attributes in each site, and (4) the relation of actual travel time, self-reported travel time, and interaction patterns.

Interaction patterns in the buildings

Interaction patterns regarding each building in each campus are broken down into (1) interaction in the same building, including (1.1) interaction on the same floor, and (1.2) interaction on different floors in the same building, and (2) interaction in different buildings in the campus. The results form the analysis of the relation of the interaction patterns and locations from each campus are illustrated below.

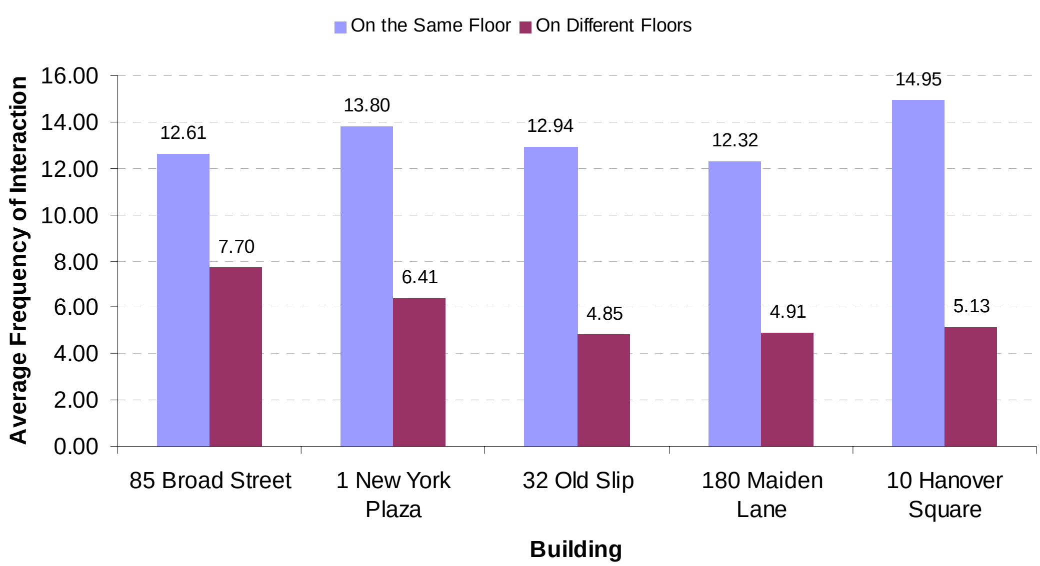


Figure 3.01 Interaction Patterns within the Same Building in GS Campus

Employing K-Wallis test for nonparametric data, there is no significant differences among the interactions in the same floor of each study building ($p = 0.221$)

in GS campus. However, the frequencies of the meeting on the different floors in the same building are significant differences, as p = 0.014. Figure 3.01 above clearly shows the differences of the average frequency of meeting on the same floor and the meeting on different floor in the same building.

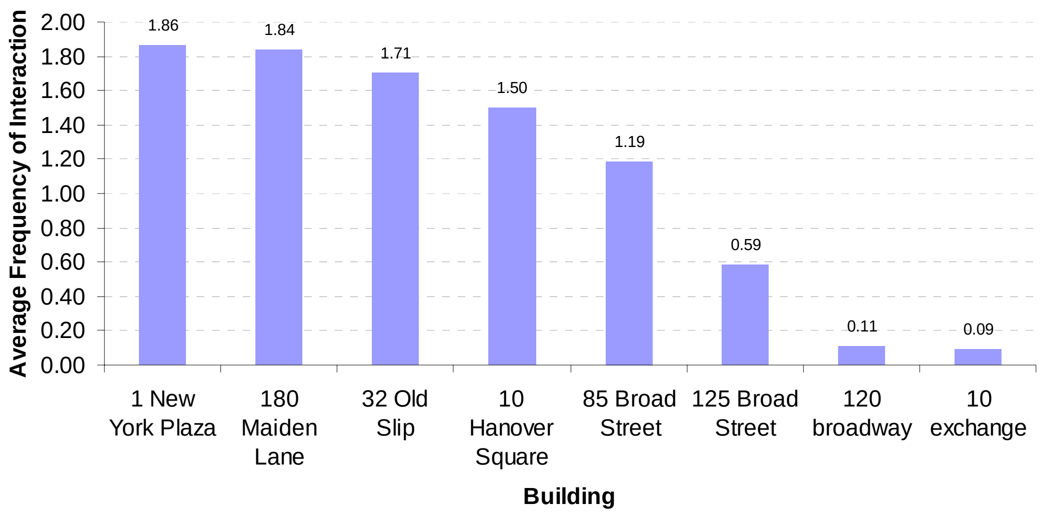


Figure 3.02 Interaction Patterns in Different Buildings in GS Campus

For interaction happening in different buildings, Figure 3.02 illustrates the average of the interaction frequencies. There are significant differences (p=0) in the frequency among the buildings.

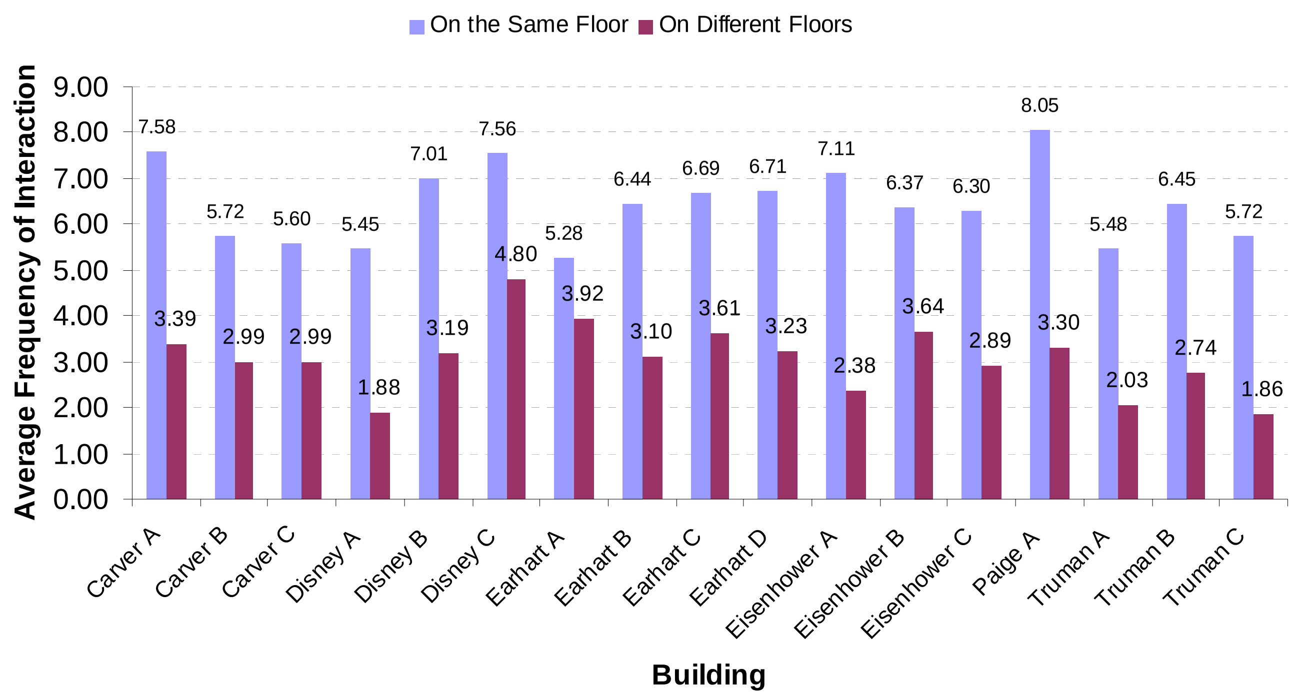


Figure 3.03 Interaction Patterns within the Same Building in Sprint Campus

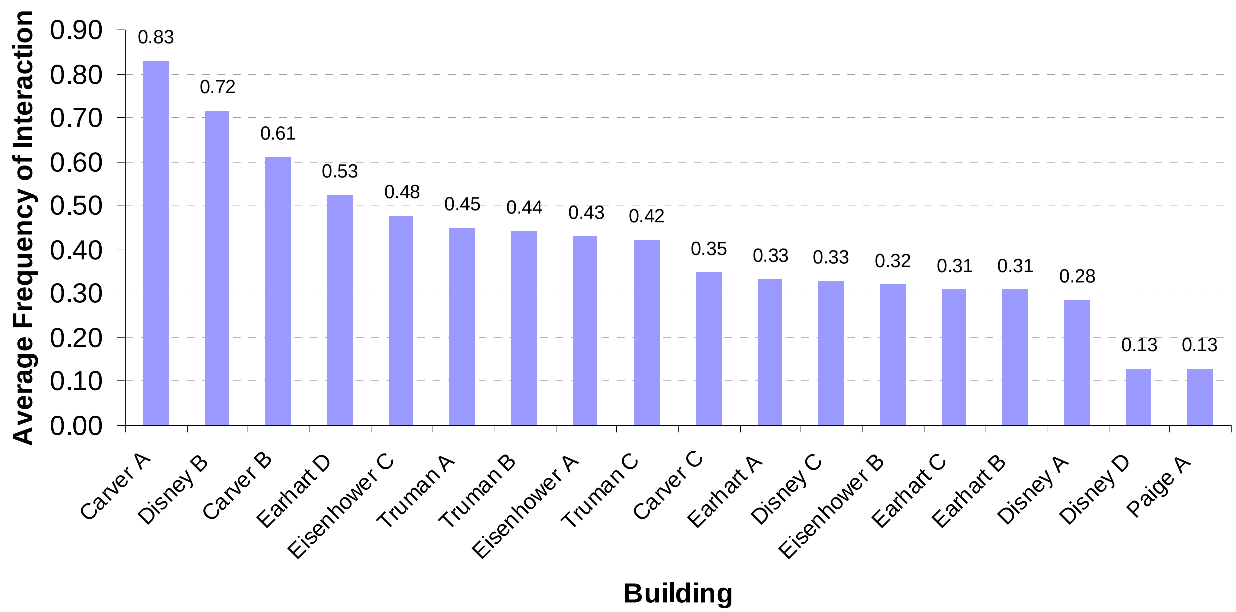


Figure 3.04 Interaction Patterns in Different Buildings in Sprint Campus

In Sprint campus, there are significant differences of the interactions both in the same floor and those of different floors (p = 0). For interaction in different buildings, there also are significant differences (p=0). Figure 3.03 and Figure 3.04 illustrated the average interactions happen in the same building and in different buildings respectively.

For the Sun campus, significant differences are found, with p=0, both the interaction patterns within the same building (Figure 3.05), and those that happen in different buildings (Figure 3.06).

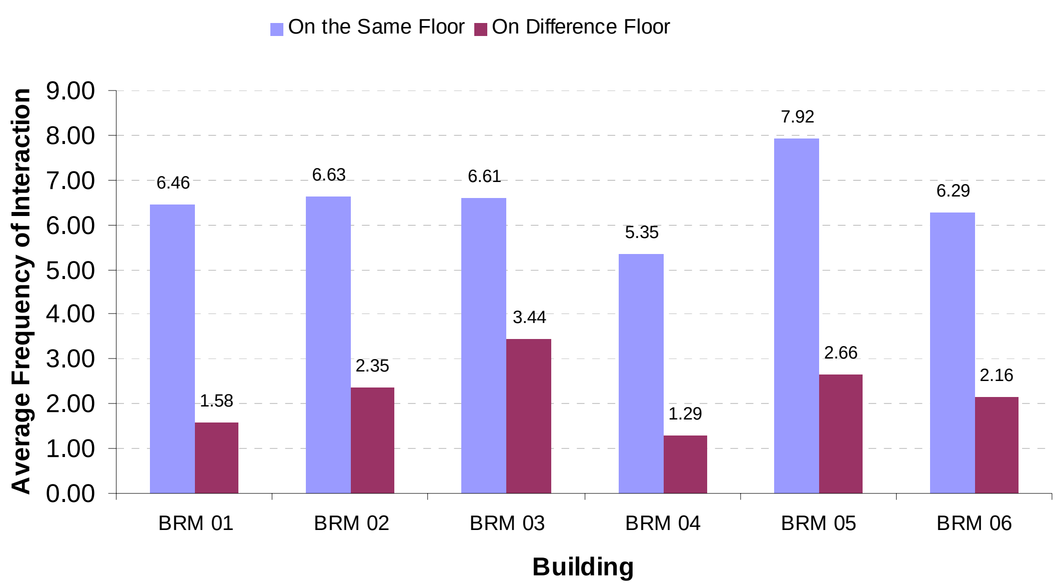


Figure 3.05 Interaction Patterns within the Same Building in Sun Campus

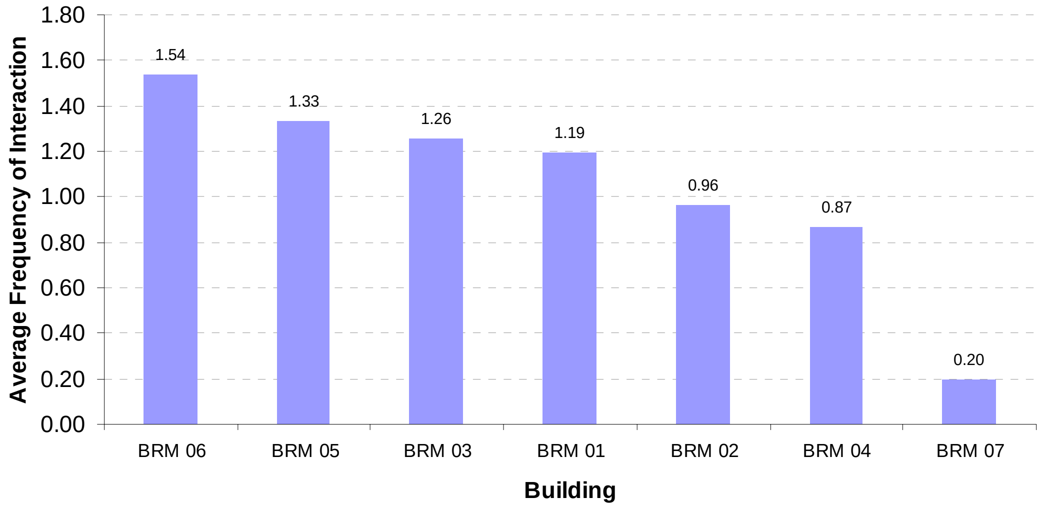


Figure 3.06 Interaction Patterns in Different Buildings in Sun Campus

Significant differences (p=0) are also found for the interaction patterns in the same building (Figure 3.07). There are also significant differences (p=0) in the interaction patterns occurring in different buildings (Figure 3.08).

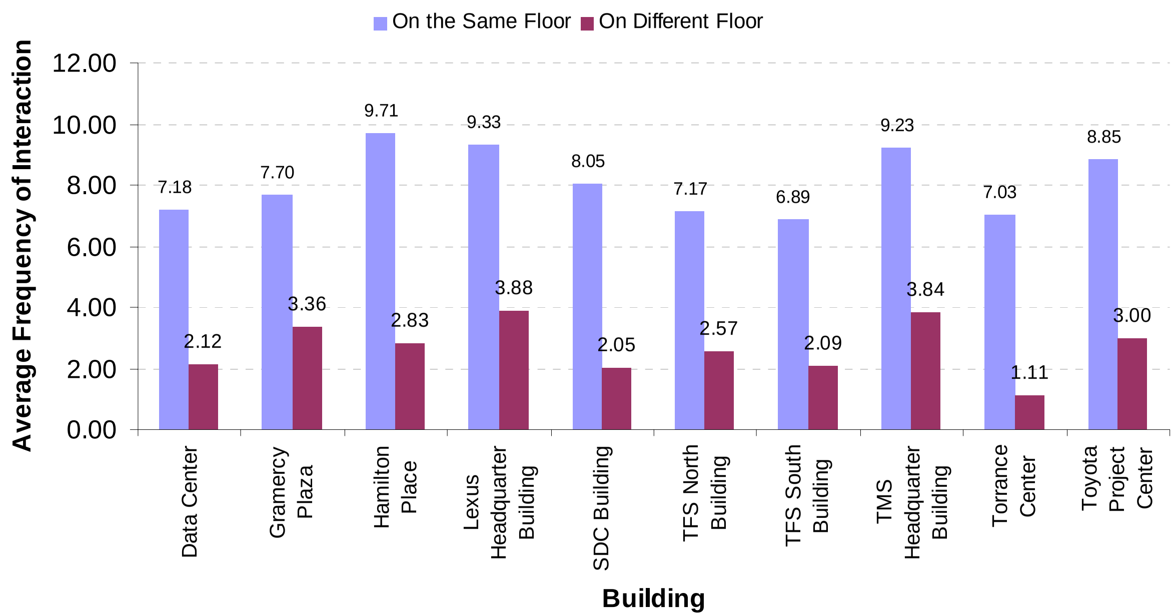


Figure 3.07 Interaction Patterns within the Same Building in TMS Campus

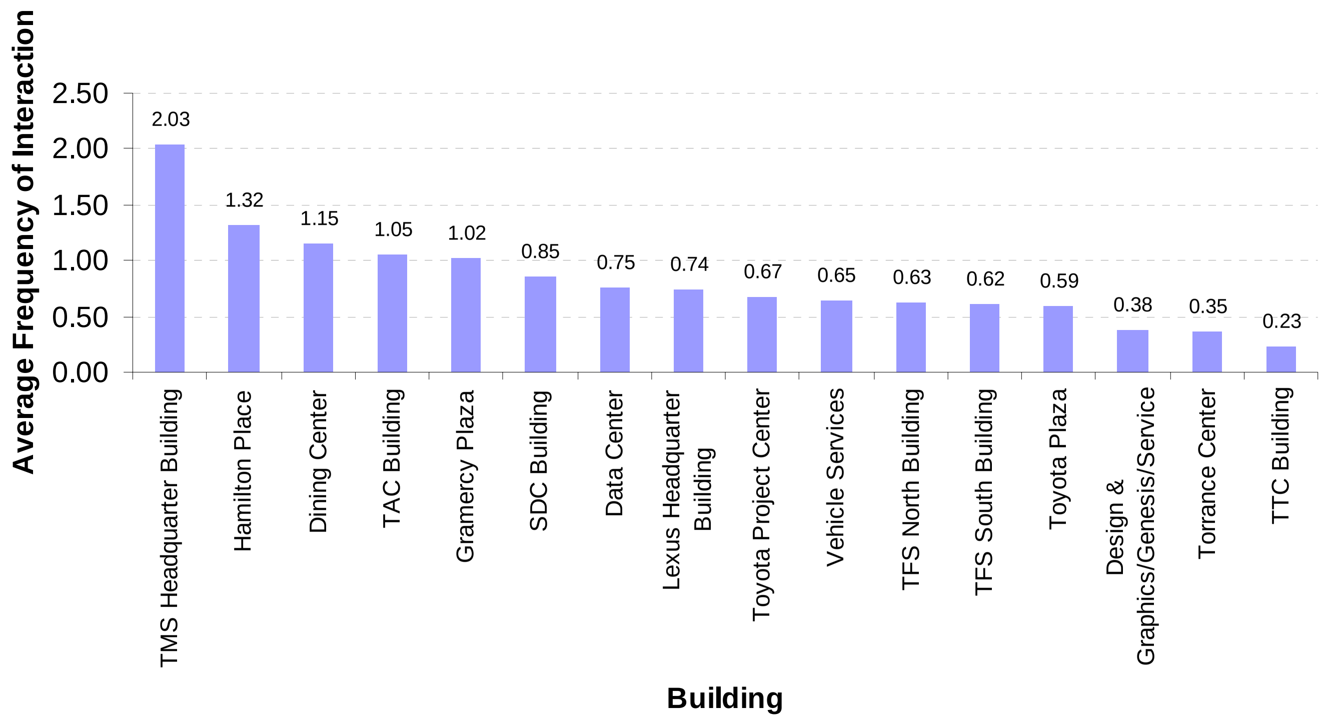


Figure 3.08 Interaction Patterns in Different Buildings in TMS Campus

Main Characteristics of Spatial Distribution

Spatial attributes of each building in the study sites are measured using the method described in Chapter 2. For the networks of the distances and travel time among the buildings in the campus are represented with a radar-like graph so that each building's distances and travel time from/to the other buildings in the same campus can be seen in comparison with the other buildings. For the whole campus, the integration of the layout of each campus is calculated and then illustrated by the colored axial map. Floor plate area and floor plate compactness are also calculated for each building. In addition to the radar-like graph, the average distances and the average travel time from, or to, each building to the other buildings in the same campus are computed to study the dispersion pattern of the buildings.

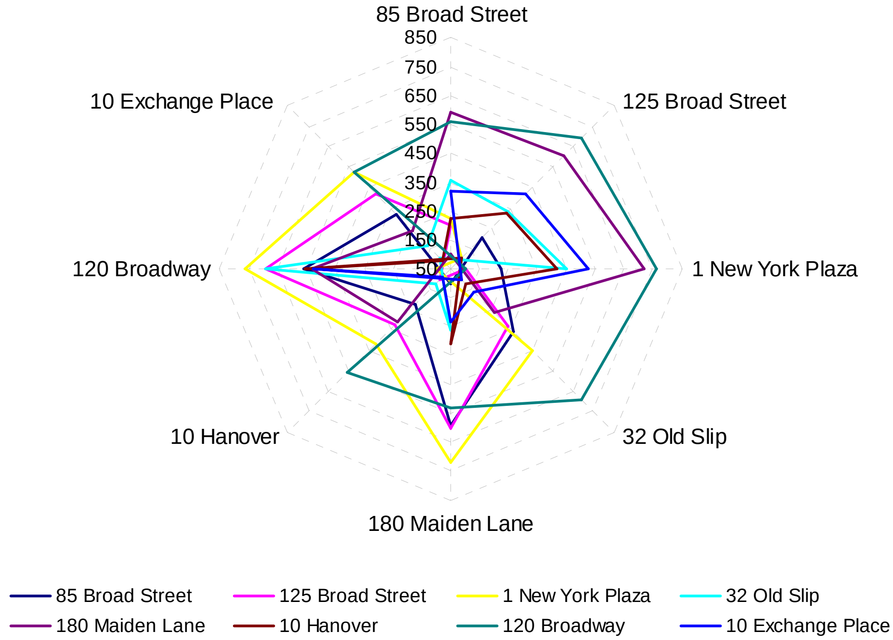


Figure 3.09 Distance Network Profile of GS Campus

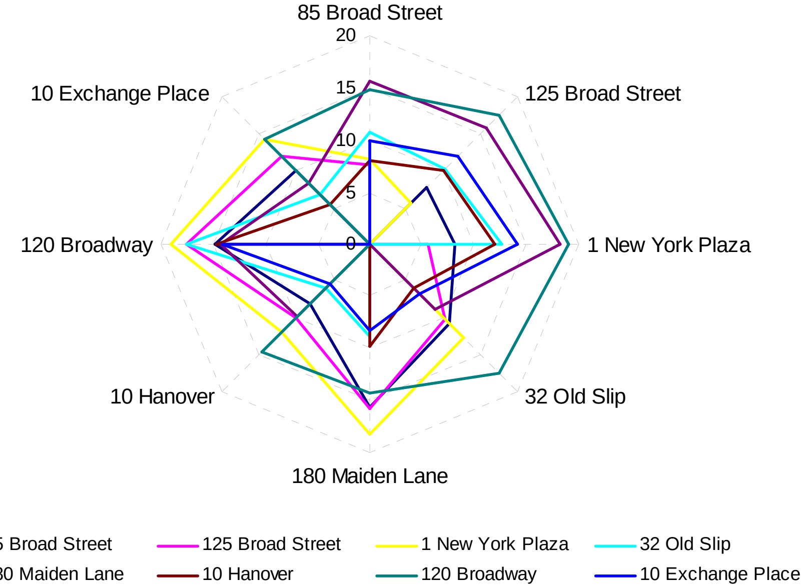


Figure 3.10 Travel Time Network Profile of GS Campus

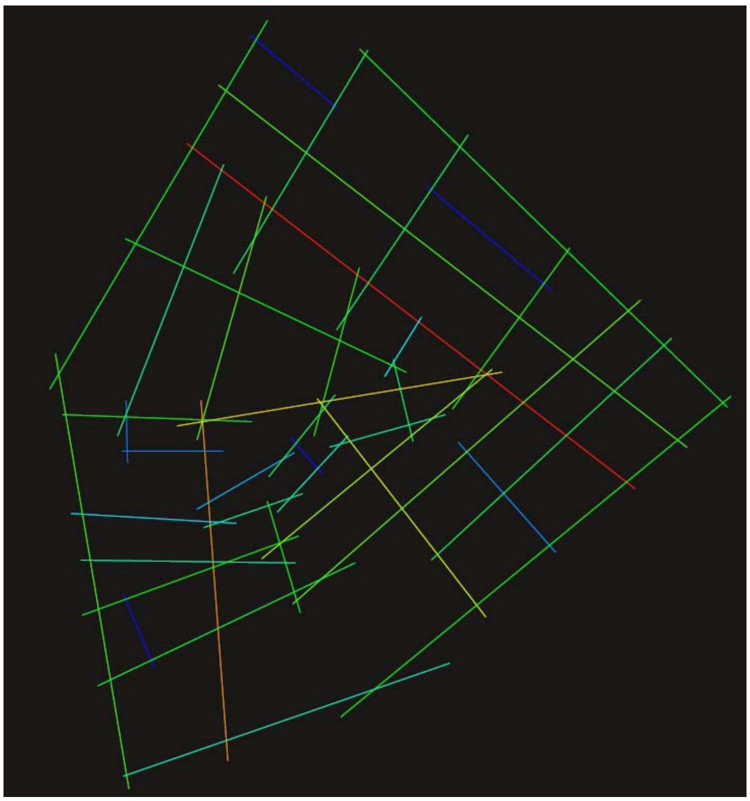


Figure 3.11 Axial Map (Integration 3) of GS Campus

Exhibit 3.01 Summary Spatial Attributes Characteristics of GS Campus

Building	Average Distance (m.)	Average Travel Time (minute)	Floor Plate Area (sq. m.)	Floor Plate Compactness
85 Broad Street	353	10.69	3,432	2.07
125 Broad Street	381	11.26	3,407	1.61
1 New York Plaza	458	12.82	4,564	1.04
32 Old Slip	339	10.40	3,247	1.00
180 Maiden Lane	463	12.94	2,924	1.00
10 Hanover	290	9.41	2,092	1.33
120 Broadway	615	16.03	4,268	5.47
10 Exchange Place	324	10.10	1,848	1.00
Mean	402.89	11.71	3,222.73	1.82
Standard Deviation	37.27	0.76	333.41	0.54

In the GS campus, most of buildings are located within 750 meters walking radius from each other (Figure 3.09). The employees can physically reach every one working in the campus within 20 minutes of walking (Figure 3.10). The most possible path (the red line) that people tend to use to meet each other informally is the path located between the two buildings locate at the west edge of the campus-120 Broadway and 180 Maiden Lane, and the rest of the buildings that cluster together (Figure 3.11). According to Exhibit 3.01, the 120 Broadway Building tends to be the farthest building from the others. While the 10 Exchange Place building has smallest floor plate area (less than 2,000 square meters), the 120 Broadway Building is also has less floor plate compactness (the ratio is 5.47), compare to other buildings, which have the ratio around 1-2.

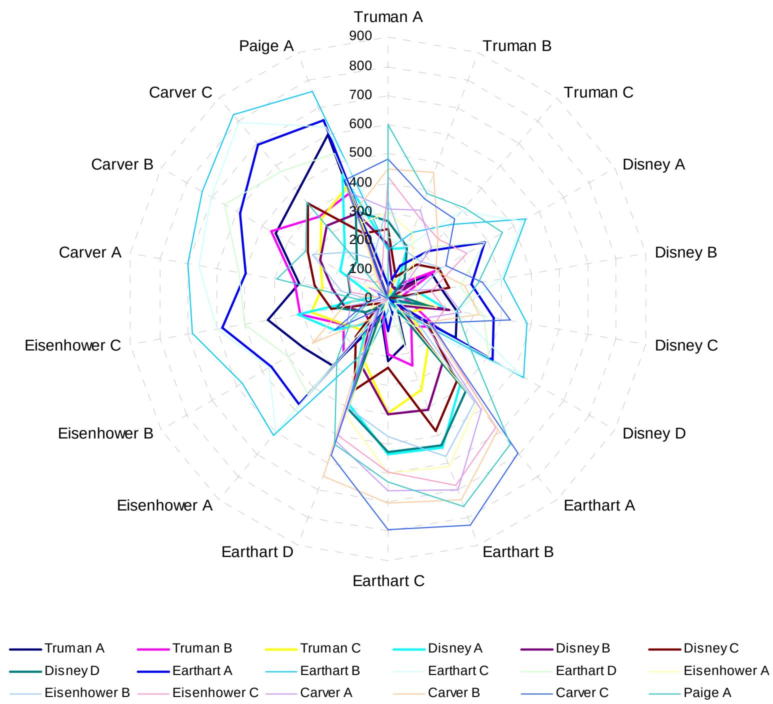


Figure 3.12 Distance Network Profile of the Sprints Campus

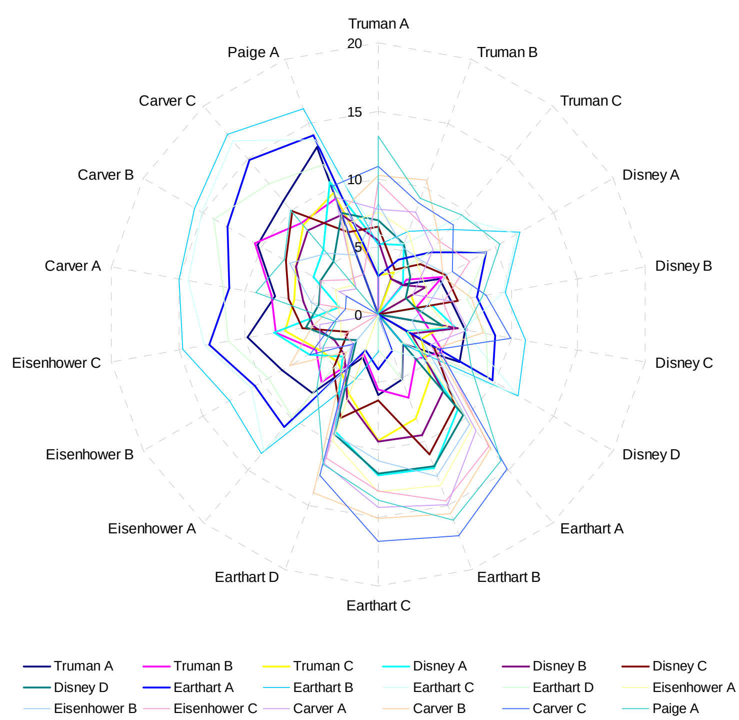


Figure 3.13 Travel Time Network Profile of Sprint Campus

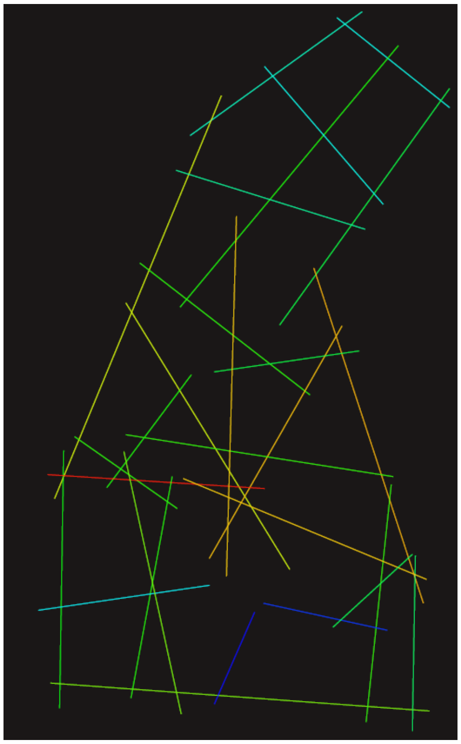


Figure 3.14 Axial Map (Integration 3) of Sprint Campus

Exhibit 3.02 Summary Spatial Attributes Characteristics of Sprint Campus

Building	Average Distance (m.)	Average Travel Time (minute)	Floor Plate Area (sq. m.)	Floor Plate Compactness
Truman A	256	6.73	3,948	3.74
Truman B	205	5.80	7,693	6.36
Truman C	204	5.77	4,197	3.93
Disney A	243	6.51	3,736	3.16
Disney B	202	5.74	3,762	3.28
Disney C	241	6.46	4,022	4.45
Disney D	218	6.04	2,692	3.23
Earthart A	352	8.51	4,580	3.19
Earthart B	463	10.57	3,851	4.80
Earthart C	419	9.76	3,766	3.73
Earthart D	327	8.06	4,753	4.46
Eisenhower A	222	6.11	3,843	2.75
Eisenhower B	231	6.28	4,470	5.28
Eisenhower C	277	7.13	6,331	5.99
Carver A	277	7.13	6,733	5.82
Carver B	339	8.28	3,801	2.91
Carver C	357	8.61	3,948	3.14
Paige A	407	9.53	3,145	3.60
Mean	291.12	7.39	4,403.75	4.10
Standard Deviation	19.29	0.36	299.71	0.27

For Sprint campus, all of the buildings are located within an approximately 800-meter walking radius from each other (Figure 3.12), or within 18 minutes of walking (Figure 3.13). The highest integration path is the path that links the east side of the campus to the center (Figure 3.14). However, as Exhibit 3.02 illustrates, the buildings tend to be well distributed around the campus, with the standard deviation of the average travel time is only 0.36 minute.

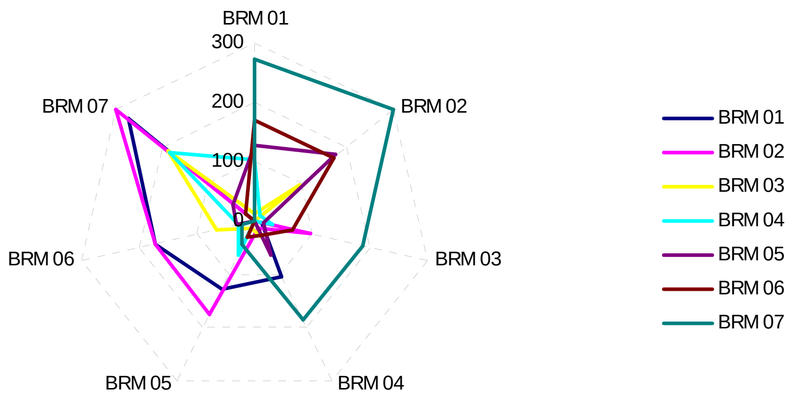


Figure 3.15 Distance Network Profile of Sun Campus

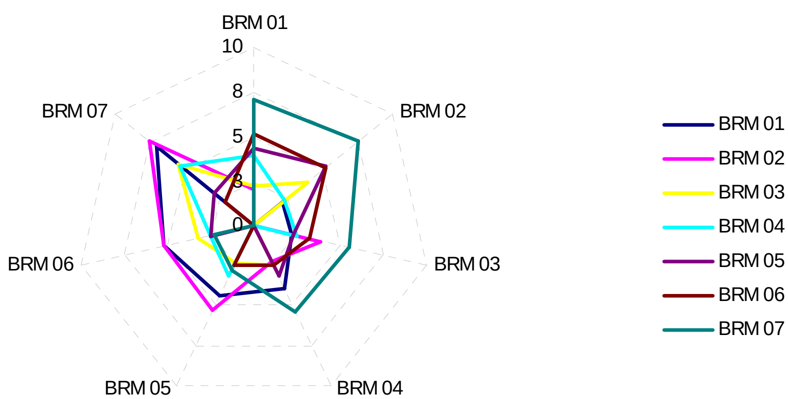


Figure 3.16 Travel Time Network Profile of Sun Campus

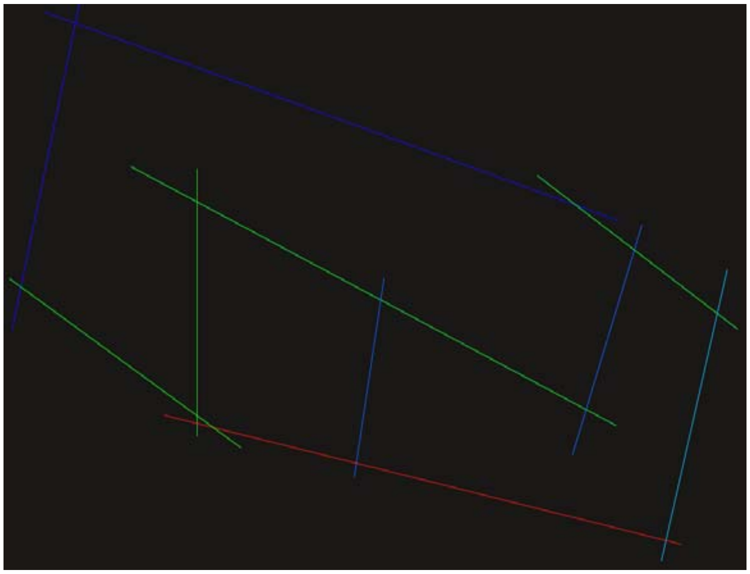


Figure 3.17 Axial Map (Integration 3) of Sun Campus

Exhibit 3.03 Summary Spatial Attributes Characteristics of Sun Campus

Building	Average Distance (m.)	Average Travel Time (minute)	Floor Plate Area (sq. m.)	Floor Plate Compactness
BRM 01	115	4.12	6,481	6.28
BRM 02	126	4.33	5,206	3.50
BRM 03	68	3.26	5,712	2.49
BRM 04	70	3.29	5,618	2.60
BRM 05	76	3.41	6,820	3.70
BRM 06	81	3.50	5,853	3.50
BRM 07	168	5.06	5,157	3.28
Mean	100.63	3.85	5,835.00	3.62
Standard Deviation	14.13	0.25	234.22	0.48

As shown on Figure 3.15, all buildings in the Sun campus are located within a 300-meter walking radius from each other, or within 8 minutes of walking (Figure 3.16). The path that links the south side of the campus is the highest integration path (Figure 3.17). The average travel time in the campus is only 3.85 minutes, with only 0.25-minute standard deviation (Exhibit 3.03. These illustrate that the campus is a small-size and highly clustered group of buildings.

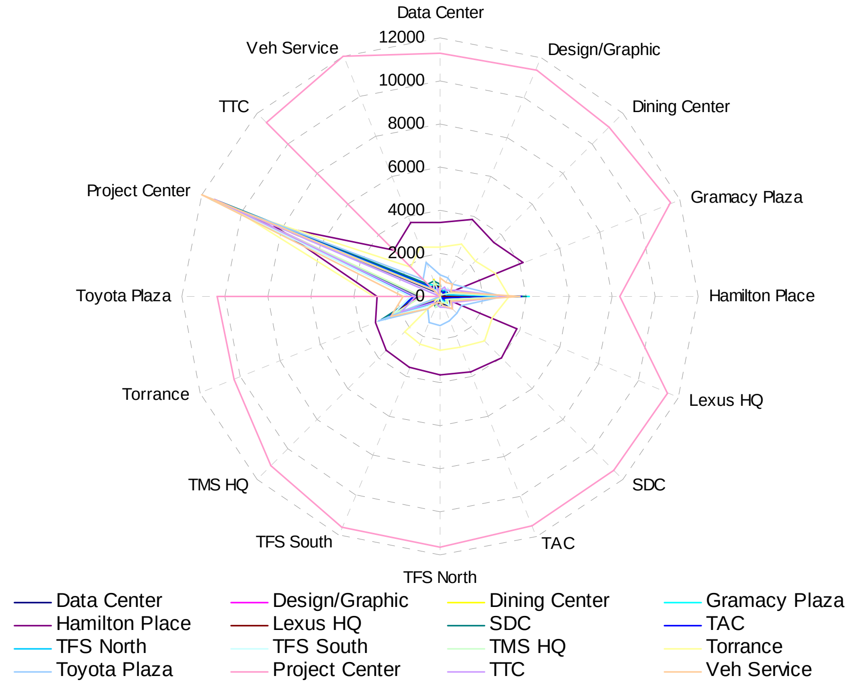


Figure 3.18 Distance Network Profile of TMS Campus (All Buildings)

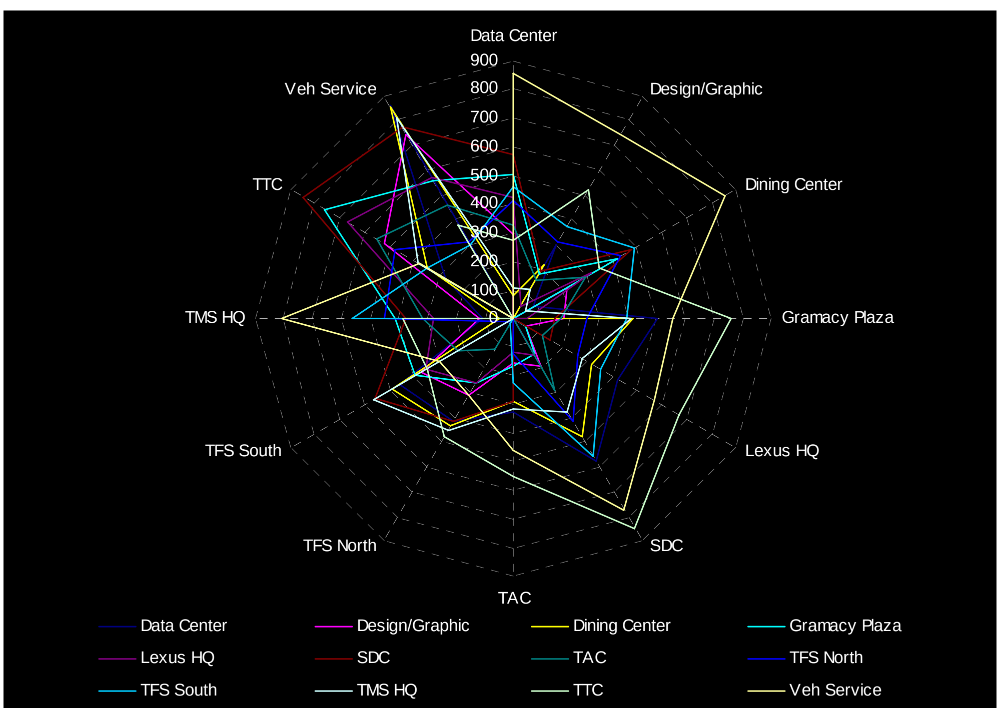


Figure 3.19 Distance Network Profile of TMS Campus (In-campus Buildings only)

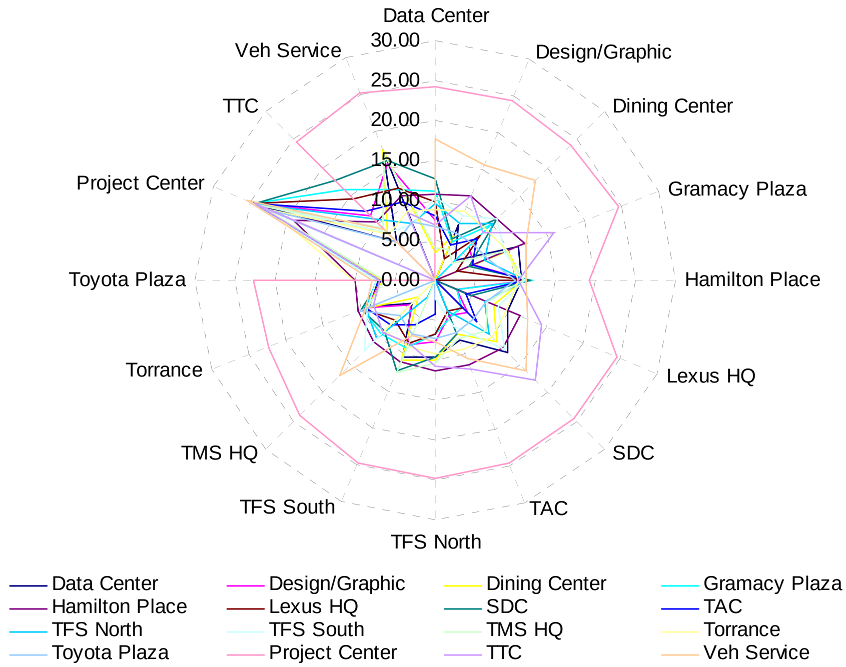


Figure 3.20 Travel Time Network Profile of TMS Campus (All Buildings)

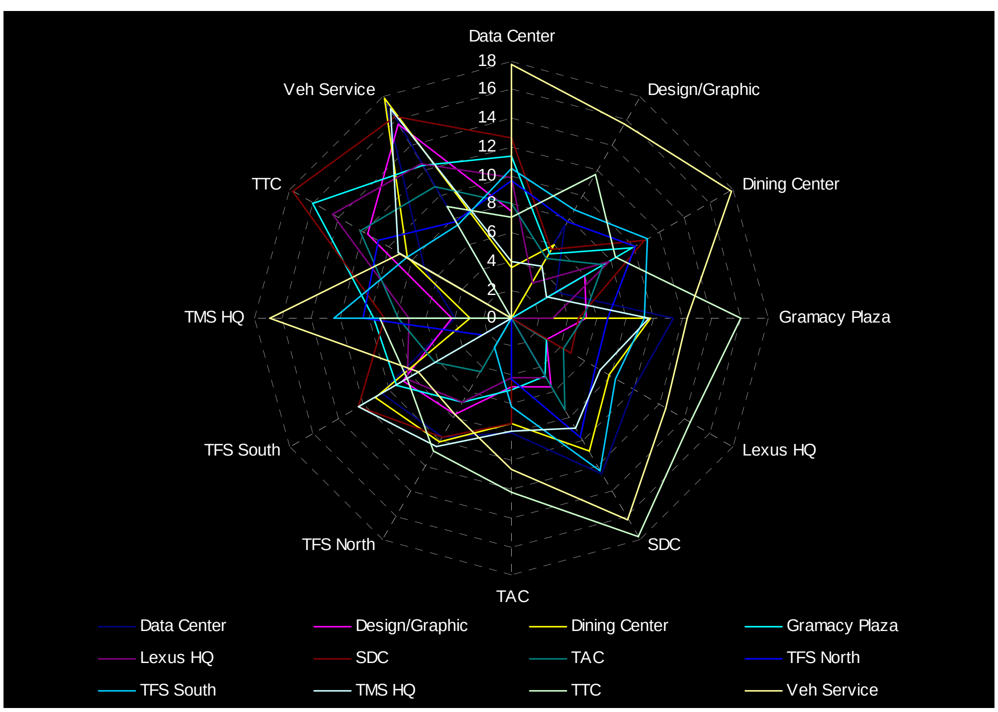


Figure 3.21 Travel Time Network Profile of TMS Campus (In-campus Buildings only)

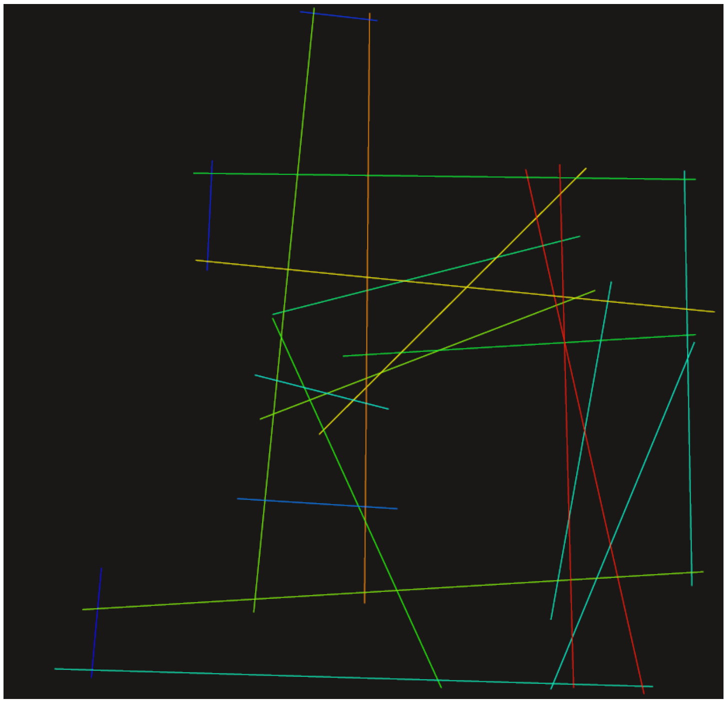


Figure 3.22 Axial Map (Integration 3) of TMS Campus (for in campus building only)

Exhibit 3.04 Summary Spatial Attributes Characteristics of Sun Campus

Building	Average Distance (m.)	Average Travel Time (minute)	Floor Plate Area (sq. m.)	Floor Plate Compactness
Data Center	1,476	10.14	3,787	1.06
Design/Graphic	1,456	8.79	3,839	3.54
Dining Center	1,450	9.71	1,164	1.18
Gramacy Plaza	1,562	9.76	3,119	3.78
Hamilton Place	3,894	11.68	7,629	8.82
Lexus HQ	1,482	8.94	2,852	1.42
SDC	1,606	10.89	4,249	5.06
TAC	1,460	8.67	2,868	1.19
TFS North	1,497	9.23	3,255	2.62
TFS South	1,532	9.96	2,919	2.35
TMS HQ	1,438	9.57	11,523	1.21
Torrance	3,075	10.27	2,456	1.75
Toyota Plaza	2,001	8.43	1,938	1.69
Project Center	11,041	23.93	11,736	11.70
TTC	1,536	11.63	2,883	1.19
Veh Service	1,760	13.17	788	1.01
Mean	2,391.69	10.92	4,187.63	3.10
Standard Deviation	601.62	0.92	817.83	0.77

TMS workplace consists of the buildings clustered in walking distance, or in-campus buildings, and buildings located outside the campus. As Figure 3.18 illustrates, the Project Center building locates farthest (around 12 kilometers) from other buildings, both in campus and off-campus, and it might take about 25 minutes for travel, by driving, from the building to reach someone working in other buildings (Figure 3.20).

However, considering only in-campus buildings, all of the buildings are located within a 900-meter walking radius from each other (Figure 3.19), or within 18 minutes of walking (Figure 3.21). For the in-campus cluster, the path that links the west side of the campus together is the highest integration path (Figure 3.22). As Exhibit 3.04 illustrates, the mixture of in-campus buildings and off-campus buildings creates a dispersed workplace in terms of distances and travel time from building to building.

Interaction patterns and physical attributes

To study the relationships between interaction patterns and physical attributes, scatter plots are generated using interaction pattern as dependent variables (y axis) and physical attributes as independent variables (x axis). The correlation analysis (r) between interaction patterns and physical attributes is also included.

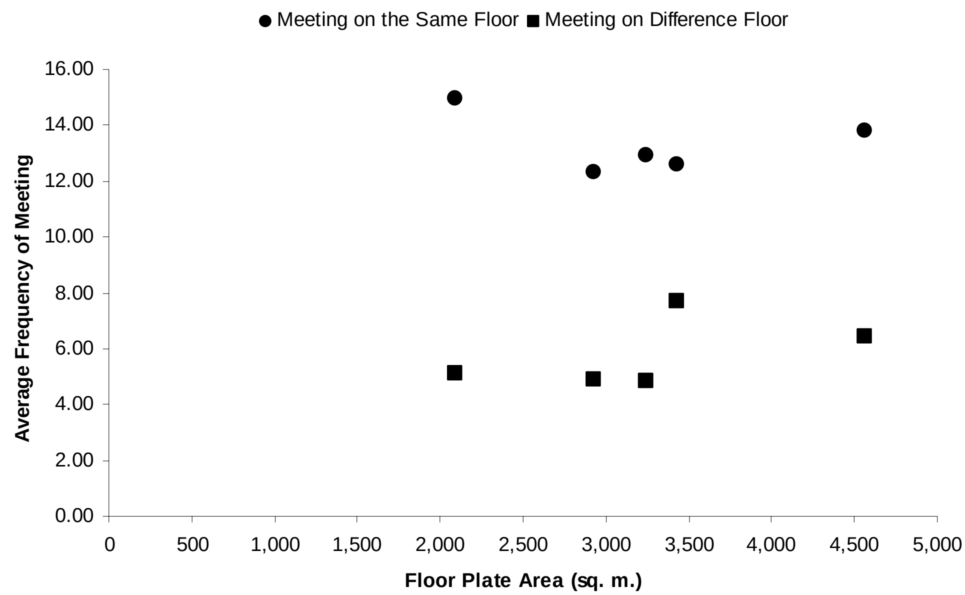


Figure 3.23 Relations between Building Area and Interaction Frequency in GS Campus

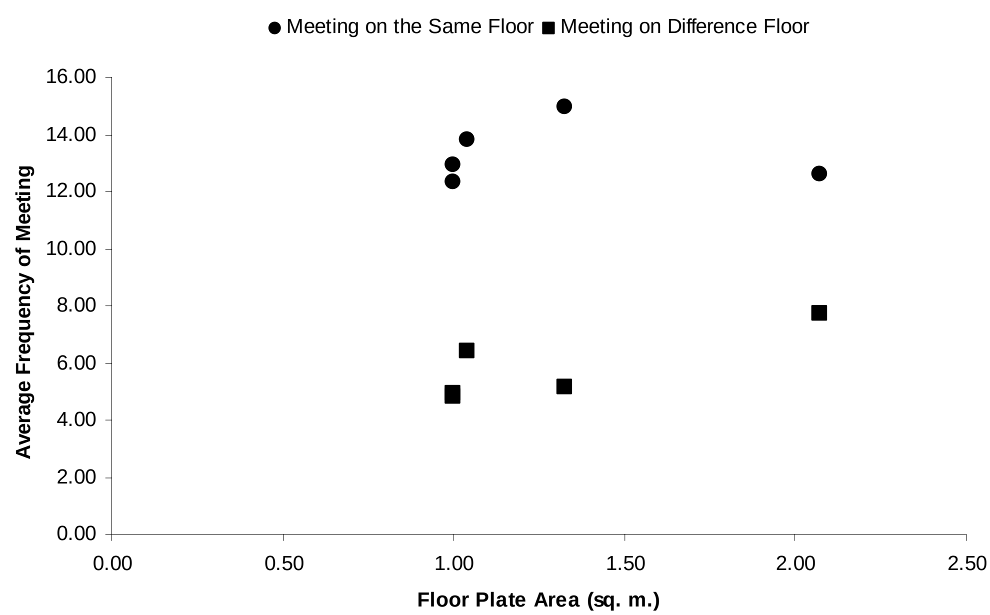


Figure 3.24 Relations between Building Compactness and Interaction Frequency in GS Campus

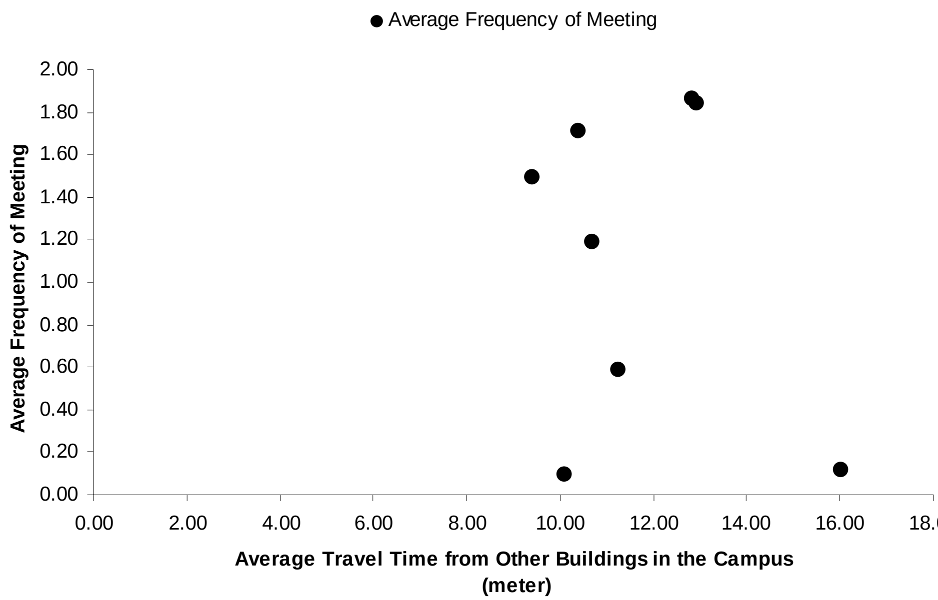


Figure 3.25 Relations between Average Travel Time from Other Buildings and Interaction Frequency in GS Campus

For GS campus, there is no obvious trend for the relation of the floor plate area and interaction patterns that happen in the same building (Figure 3.24). The correlation of the interactions in the same floor and floor plate area is – 0.28. However, the correlation of interaction in different floors and floor plate area is 0.50.

Figure 3.25 also illustrates that the relation between interaction patterns in the same building and floor plate compactness ratio tends to be weak. While the correlation of the interaction in the same floor and floor plate compactness ratio is – 0.11, that of the interaction in different floors and floor plate compactness ratio is 0.81, much stronger.

For the interaction in different buildings (Figure 3.26), the relations of the average interaction frequency and the average travel time from other buildings to the building are also weak (r= 0.47).

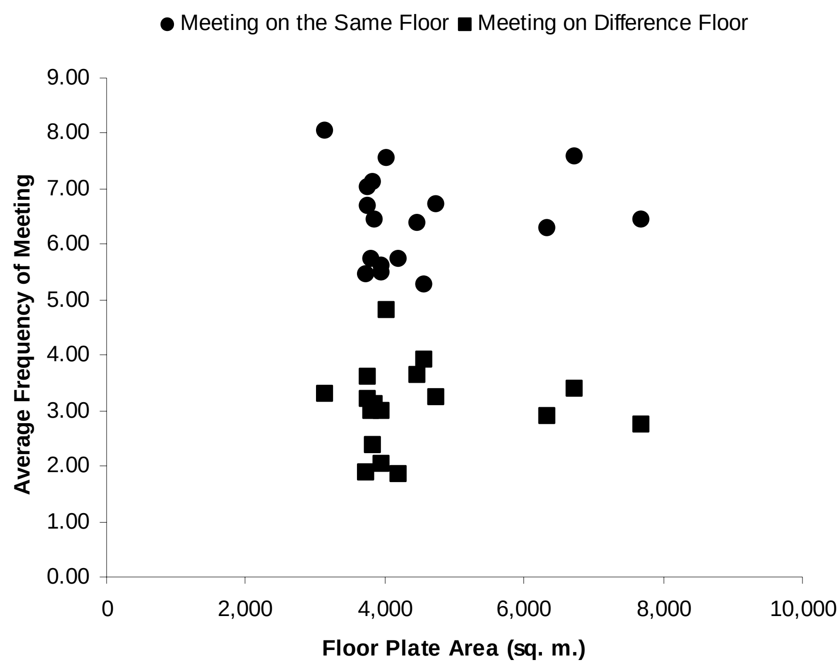


Figure 3.26 Relations between Building Area and Interaction Frequency in Sprint Campus

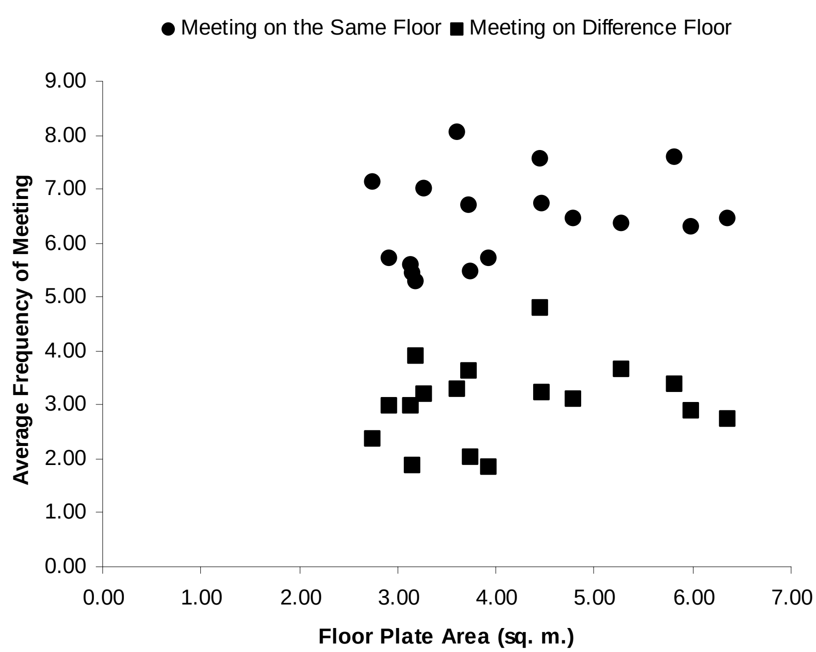


Figure 3.27 Relations between Building Compactness and Interaction Frequency in Sprint Campus

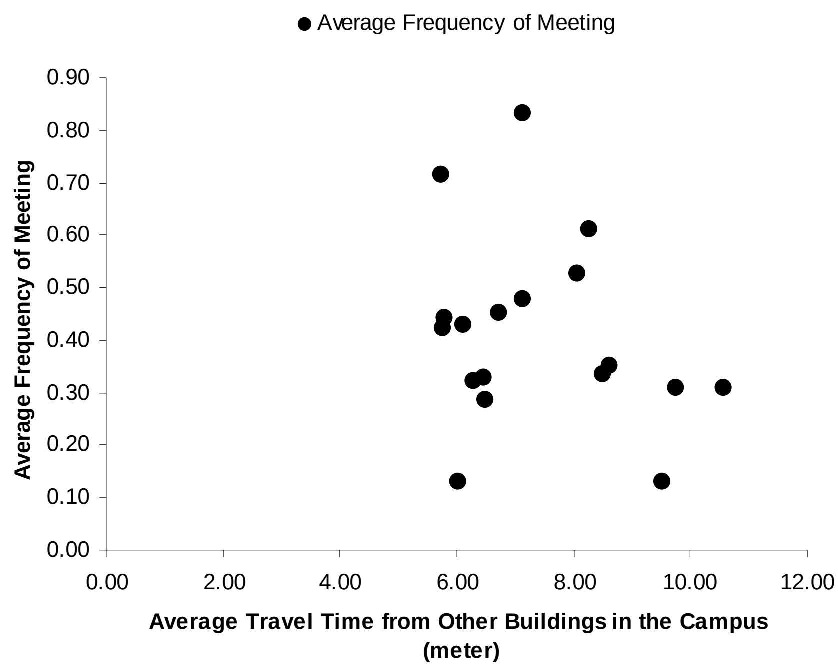


Figure 3.28 Relations between Average Travel Time from Other Buildings and Interaction Frequency in Sprint Campus

In the Sprint campus, the correlation of the interactions in the same floor and floor plate area is 0.06, and that of the interaction in different floors and floor plate area is 0.01 (Figure 3.26).

For the relation between interaction patterns in the same building and floor plate compactness ratio (Figure 3.27), the correlation of the interaction in the same floor and floor plate compactness ratio is –0.26. In addition, correlation of the interaction in different floors and floor plate compactness ratio is 0.18.

As shown on Figure 3.28, the relations of the average interaction frequency and the average travel time from other buildings to the building are also negative. The correlation is –0.25.

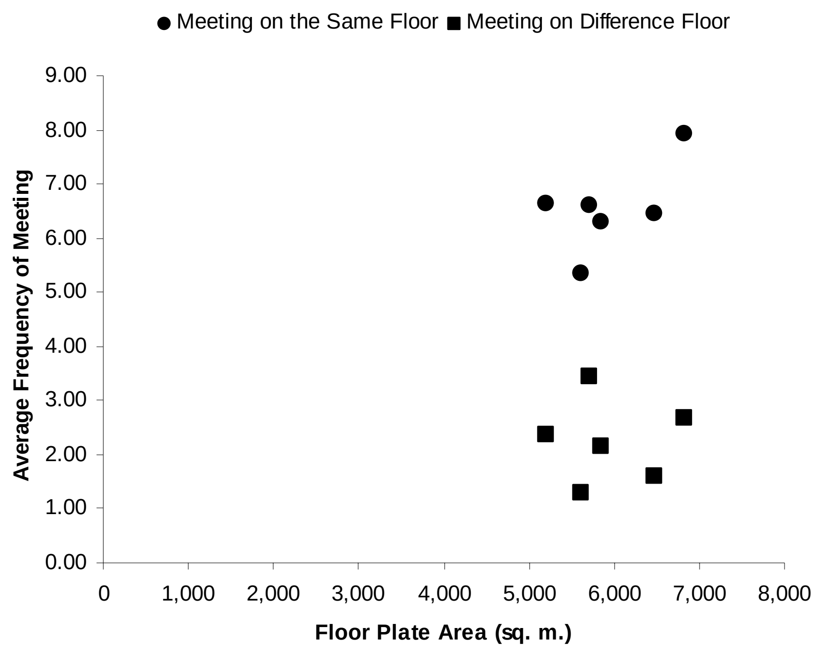


Figure 3.29 Relations between Building Area and Interaction Frequency in Sun Campus

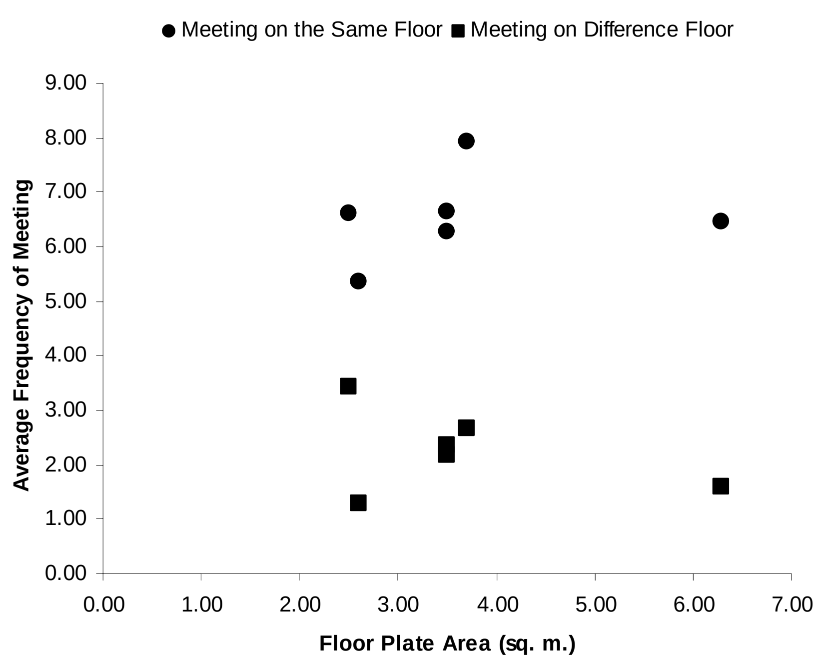


Figure 3.30 Relations between Building Compactness and Interaction Frequency in Sun Campus

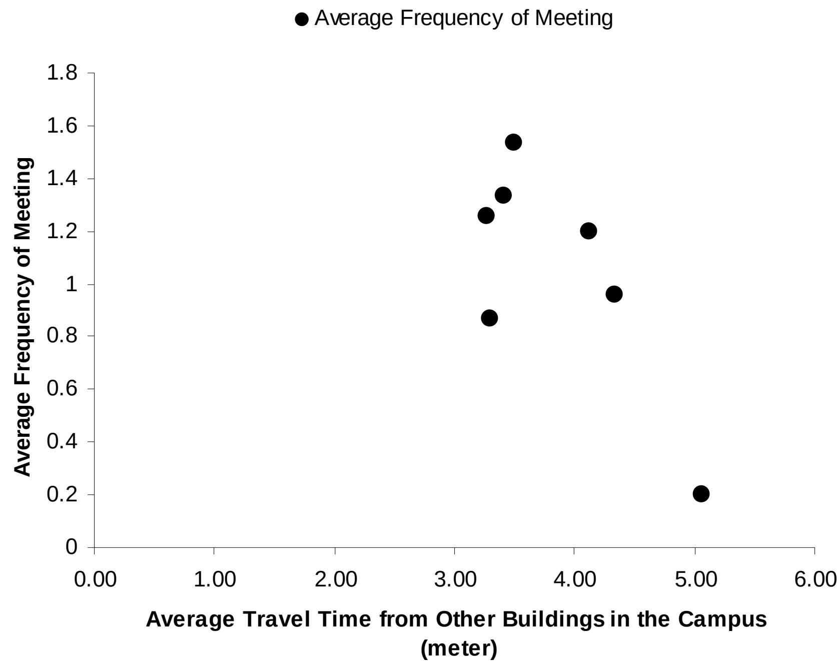


Figure 3.31 Relations between Average Travel Time from Other Buildings and Interaction Frequency in Sun Campus

For the Sun campus, while the correlation of the interactions in the same floor and floor plate area is 0.61, that of the interaction in different floors and floor plate area is relatively weak and negative, at -0.01 (Figure 3.29).

The relation between interaction patterns in the same building and floor plate compactness ratio is illustrated on Figure 3.30. The correlation of the interaction in the same floor and floor plate compactness ratio is 0.18, and that of the interaction in different floors and floor plate compactness ratio is -0.40.

In addition, the relations of the average interaction frequency and the average travel time from other buildings to the building tend to be strong and nagative, since the correlation is –0.76 (Figure 3.31).

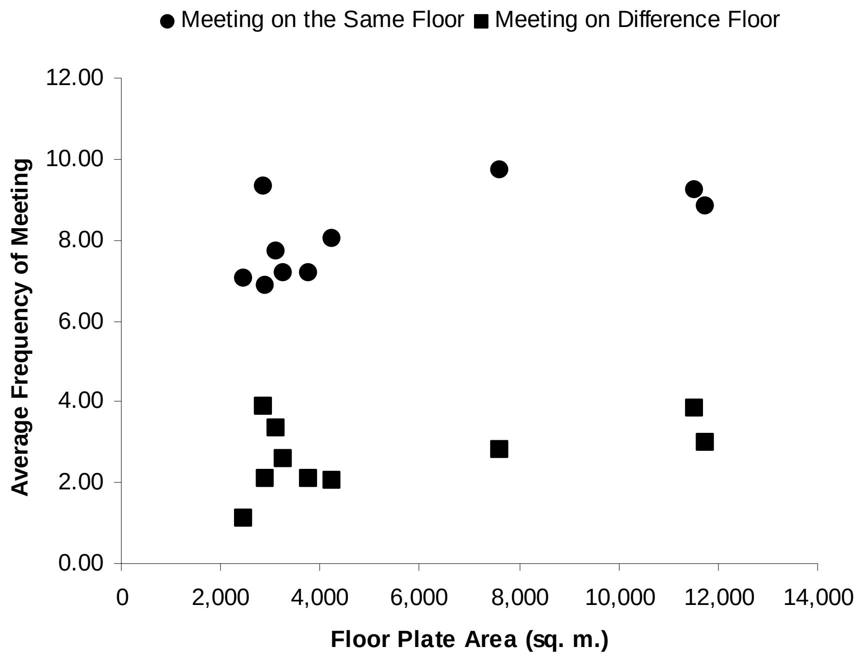


Figure 3.32 Relations between Building Area and Interaction Frequency in TMS Campus

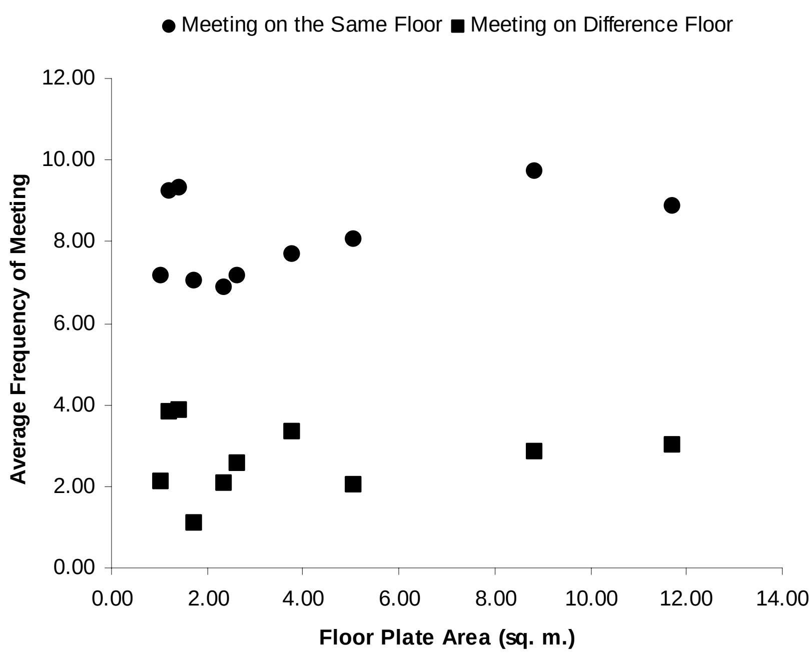


Figure 3.33 Relations between Building Compactness and Interaction Frequency in TMS Campus

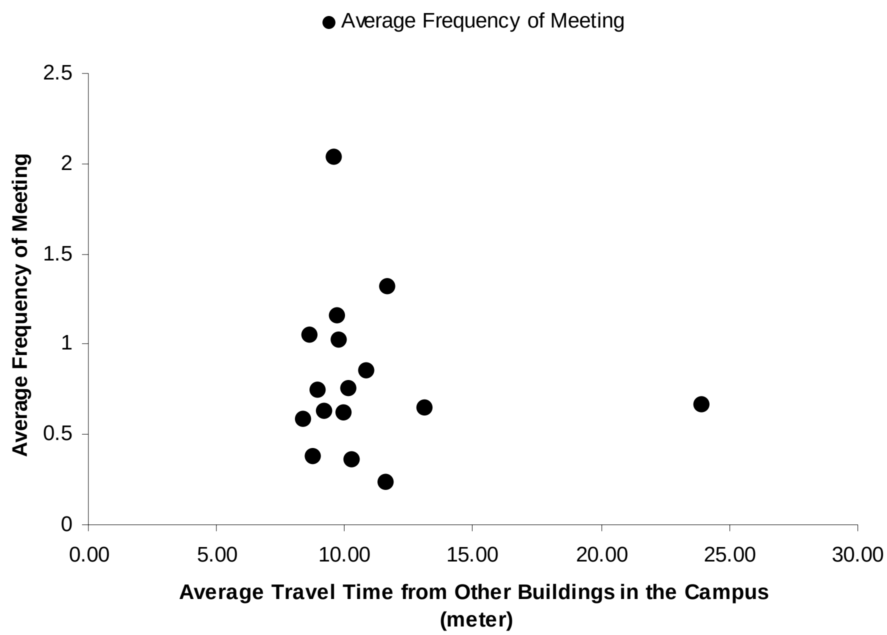


Figure 3.34 Relations between Average Travel Time from Other Buildings and Interaction Frequency in TMS Campus

In TMS campus, Figure 3.32 shows the correlation of the interactions in the same floor and floor plate area, as r= 0.64. And the correlation of the interaction in different floors and floor plate area is 0.45.

For the compactness ratio of floor plate, the relation between interaction patterns in the same building and floor plate compactness ratio is shown on Figure 3.33. The correlation of the interaction in the same floor and floor plate compactness ratio is 0.45, and that of the interaction in different floors and floor plate compactness ratio is relatively weak, at r=0.08.

As shown on Figure 3.34, the relations of the average interaction frequency and the average travel time from other buildings to the building tend to be very weak and negative, as r= –0.11

Actual Travel Time and Self-reported Travel Time

The relations of actual travel time, calculated by physical measurement and frequency of meeting, and self-reported travel time are represented on the line graph below (Figure 3.35-Figure 3.38)

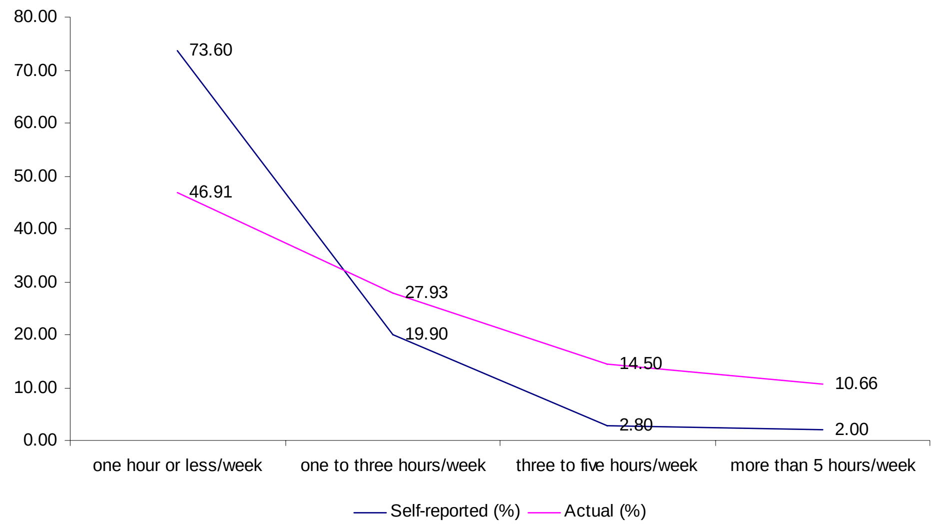


Figure 3.35 Relations between Actual Travel Time and Self-reported Travel Time in GS Campus

Using paired simples statistical test, in GS campus, there are significant differences between actual travel time and self-reported travel time ($p=0$, $n=464$). However, the correlation between them tends to be semi-strong ($r=0.50$). Figure 3.35 illustrates that the largest fraction of GS staff (74% and 47%) spend less than one hour per week for travel to and travel back from meeting held in different buildings in the campus.

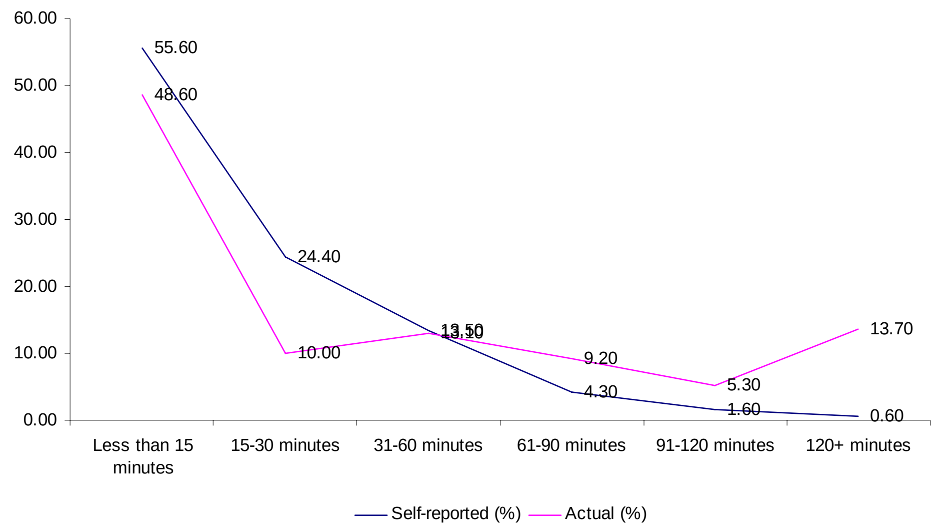


Figure 3.36 Relations between Actual Travel Time and Self-reported Travel Time in Sprint Campus

In Sprint campus (Figure 3.36), there are significant differences between actual travel time and self-reported travel time (p=0, n=1794). Similar to GS campus, the correlation between both travel times also tends to be semi-strong (r=0.58).

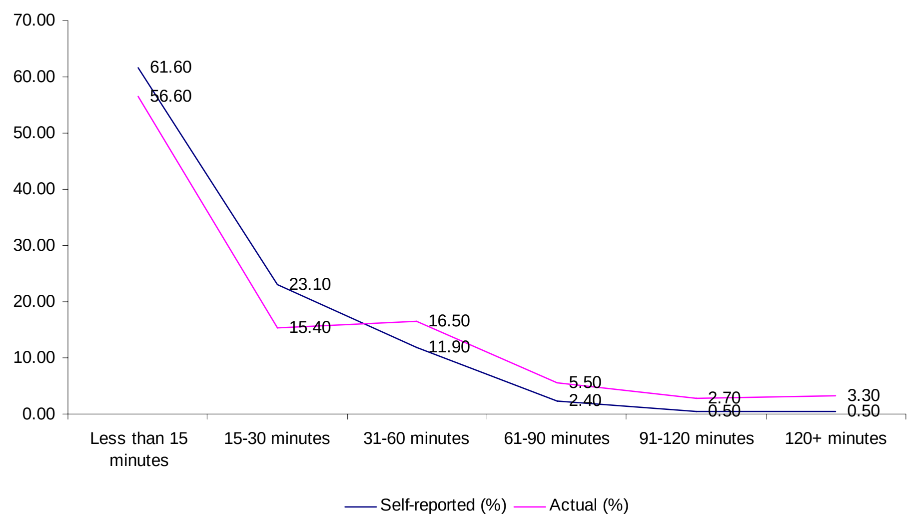


Figure 3.37 Relations between Actual Travel Time and Self-reported Travel Time in Sun Campus

As Figure 3.37 illustrates, there are significant differences between actual travel time and self-reported travel time (p=0, n=178) in Sun campus. And the correlation between both travel times also tends to be weak (r=0.43).

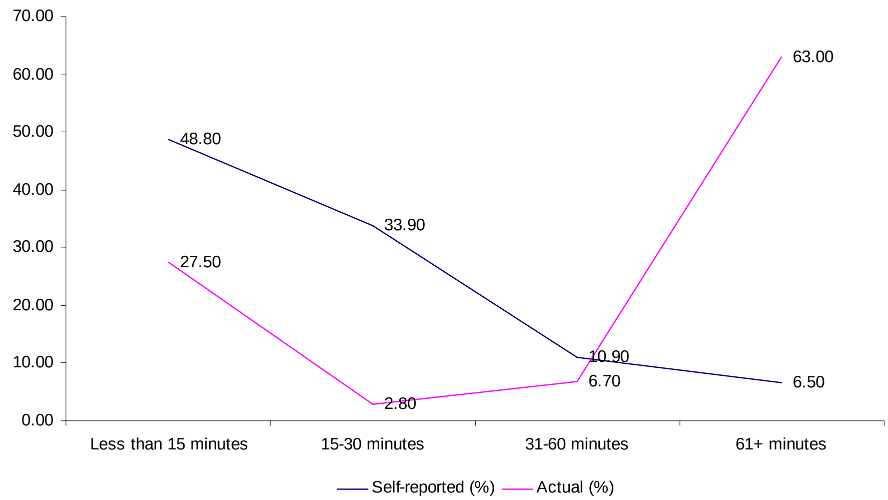


Figure 3.38 Relations between Actual Travel Time and Self-reported Travel Time in TMS Campus

In TMS campus (Figure 3.38), there is a conflict between self-reported travel time and actual travel time. While 49 percent reported they spent less than 15 minutes per week in travel to meeting, the actual travel time computed 63 percent of them might take more than an hour per week in traveling for meeting. Obviously, there are significant differences between actual travel time and self-reported travel time (p=0, n=426) in the campus. In addition the correlation between both travel times also tends to be weak (r=0.43).

Actual Travel Time and Interaction Pattern

Figure 3.39 to Figure 3.42 below illustrate the relations of actual travel time and interaction frequency. A linear regression model has been employed to investigate the relations in each campus. To predict the trend of the relationship, the travel time is applied as an independent variable, and average frequency of the meeting from each building to other buildings is a dependent variable.

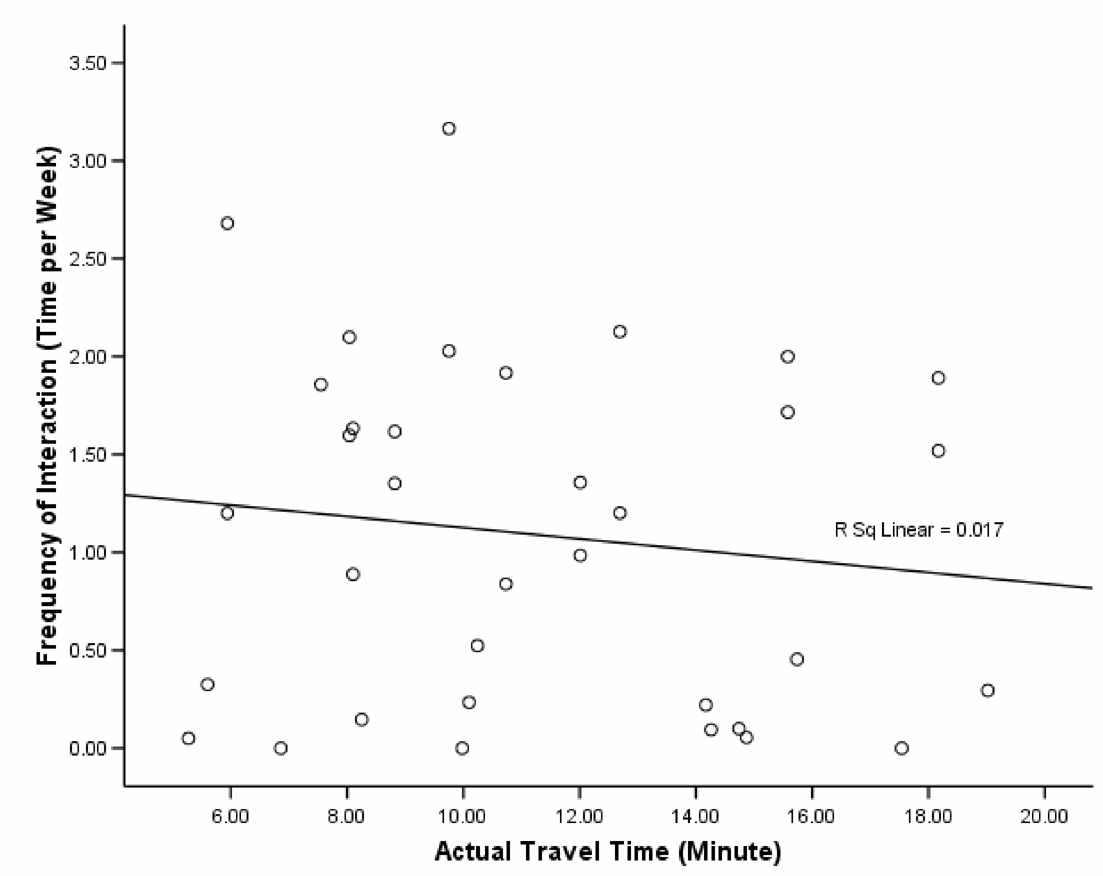


Figure 3.39 Relations between Actual Travel Time and Interactions in GS Campus

According to Figure 3.39, the regression model show R square = 0.017 and the adjusted R square = -0.013. And the p value = 0.

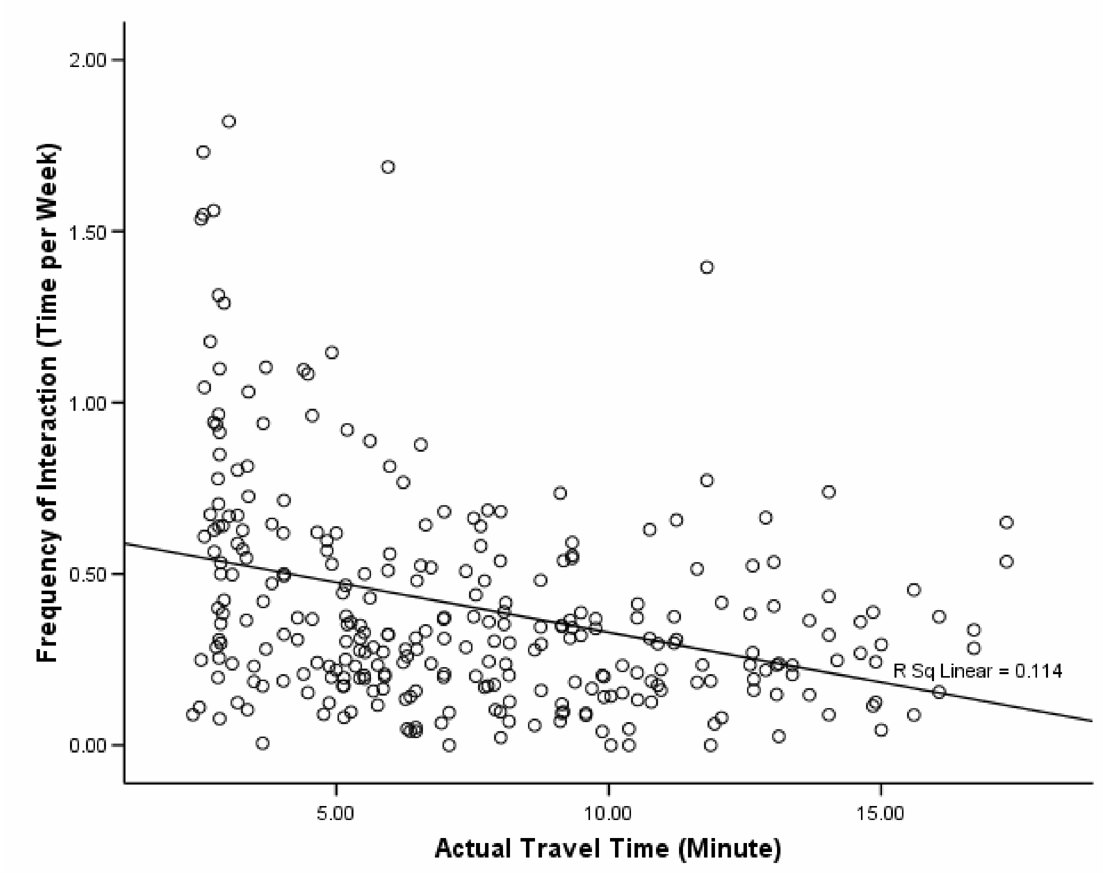


Figure 3.40 Relations between Actual Travel Time and Interactions in Sprint Campus

For Sprint campus, the R square of the model = 0.114, and the adjusted R square = 0.110. The p value = 0 (Figure 3.40).

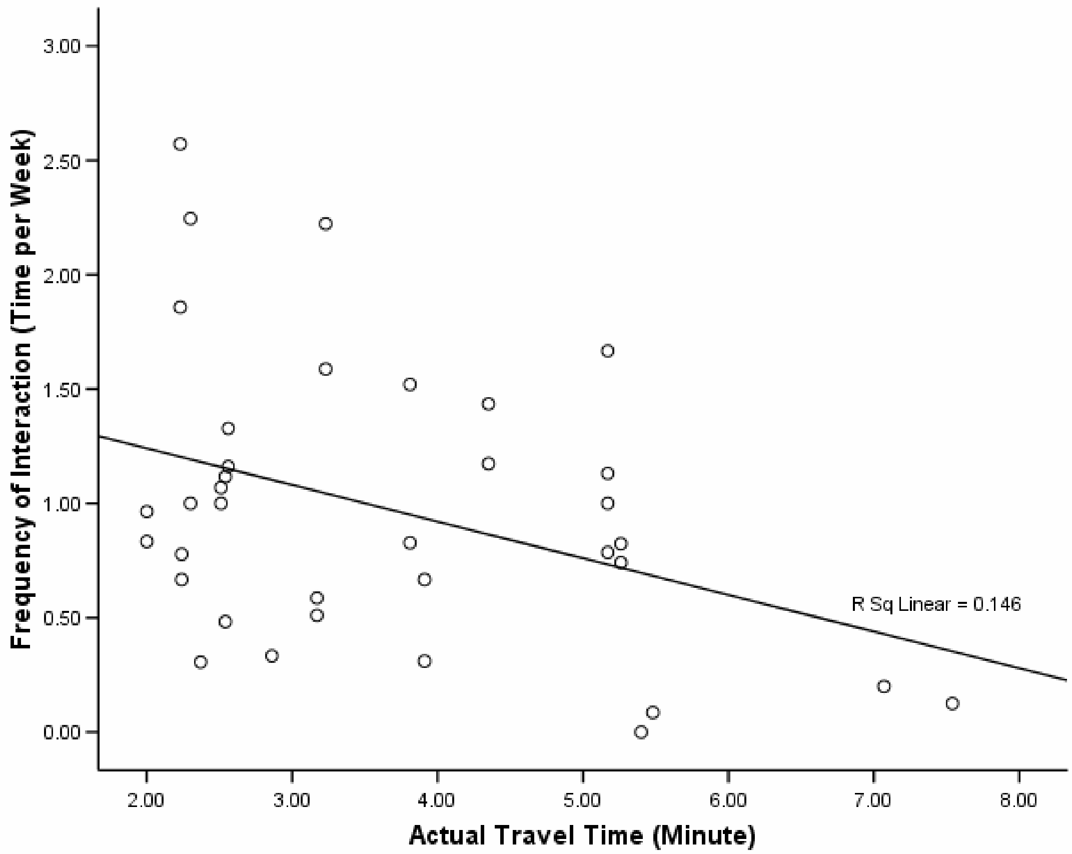


Figure 3.41 Relations between Actual Travel Time and Interactions in Sun Campus

In Sun Campus, the regression model show R square = 0.146 and the adjusted R square = 0.120. And the p value = 0.020 (Figure 3.41).

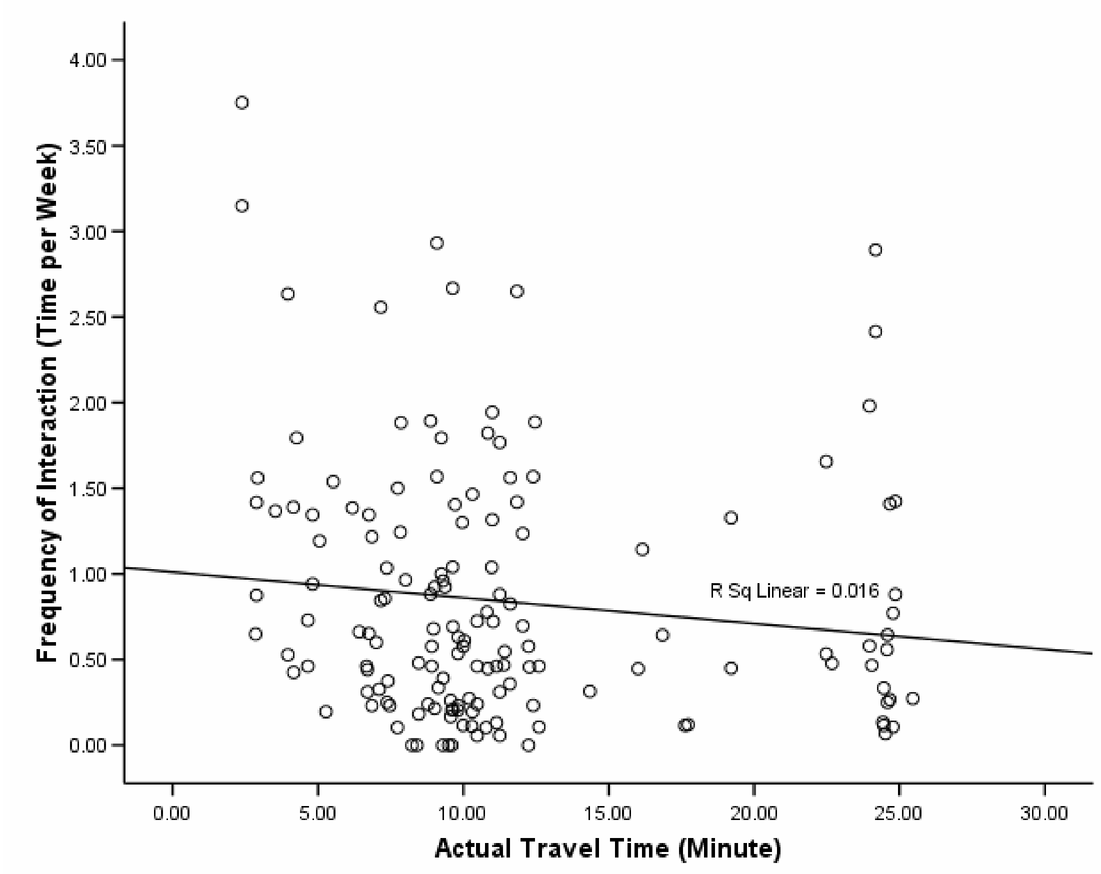


Figure 3.42 Relations between Actual Travel Time and Interactions in TMS Campus

According to Figure 3.42, the regression model for TMS campus shows R square = 0.009 and the adjusted R square = -0.013. And the p value = 0.126.

Chapter 4

Discussion and Recommendations

The results from Chapter 3 are analyzed and are interpreted in order to respond the research questions proposed in the introduction chapter. In addition to key findings and implications, this section also includes an analysis of the limitations of the research. In addition, the future prospects of the study are also proposed.

Key findings and implications

Does frequency of interaction, both interaction within each building and interaction between buildings in the same campus differ from each other?

Previous studies (Allen, 1997; Becker et. al, 2003) suggest that physical proximity affects interaction patterns. The results from this research are consistent with those findings. Within all building of the four study sites, the average frequency of interactions on the same floor is much higher than that of the different floor in the same building. The results also suggest that there might be some factors, beyond proximity, that affect the interaction patterns of the employees, since the frequency of meeting on the same floor is different from building to building, even though they are located in the same campus. On the other hand, the building that has the highest frequency of interaction on the same floor is not the building that has the highest frequency of interaction on different floors. In other words, the pattern of meeting on the same floor and meeting on different floors in the same building are independent from each other. This pattern is found consistently across the different campuses.

Similar to the interaction pattern within a building, in each campus, the interactions between buildings are also different from building to building. The highest frequency of interaction between buildings in each campus is in 1 New York Plaza building, Carver A building, BRM06 building, and TMS Headquarters building, for GS, Sprint, Sun and TMS campus respectively. However, interestingly, those buildings do not have the highest frequency of interactions happening in the same building, neither the interaction on the same floor, nor the interaction on different floors. According to the finding, meeting on the same floor, meeting on different floor, and meeting in different building do not depend on each other.

What are the main characteristics of spatial distribution, including cluster, physical distance, and travel time of each campus?

As the radar graphs in Chapter 3 show, the spatial distribution of each campus is different. The main driver of the differences comes from size and type of the campus. The main characteristics of each campus are described below:

GS Campus: Since the campus has been distributed into speculative office buildings nearby one by one as required in a built up dense urban environment, the GS campus tends to be spread-out, scattering on deformed grid street networks of lower Manhattan. The walking radius of the campus is about 750 meters. As shown on Table 3.01 and Figure 3.09, there are three buildings, including 120 Broadway building, 180 Maiden Lane building and 1 New York Plaza building, located on the outer ring. The other five buildings are located in the inner cluster. Considering the minimum average distance (190 meters) and the minimum walking time (9.41 minutes) from other building, 10 Hanover building is most likely to be the center building of the campus. The average distance from each building to other building in the campus is 403 meters, while the average walking time is about 12 minutes. The average distance and the average travel time imply that the campus is relatively large. Except for the 120 Broadway building which has an average walking time of more than 16 minutes, most of the buildings can be reached within 10 minutes to 13 minutes. In this case, all buildings seem to be distributed evenly and within walking distance.

For floor plate area, most of them have floor plate area around 3,000 m^2 to 4,500 m^2, except 10 Exchange Place building and 10 Hanover building. Both of them have floor plate area around 2,000 m^2. Half of the buildings has floor plate compactness ratio around 1, which is the ideal ratio for the workplace building according to Allen (1997). And considering Allen's (1997) suggestion, 120 Broadway building may not desirable, since its H-shape floor plate and its high ratio between floor plate's length and floor plate's width may not encourage communication between the workers who occupy the building.

The redder line in the axial map of the campus (Figure 3.11) identifies the potential routes that are by nature highly integrated routes, or the area that people tend to gather. The segregated area, or low integration, is represented in bluer color. In this case, since the GS campus is embedded in the city's grid street network, it is impossible to separate the campus from the urban fabric it is embedded in. In other words, the axial map also shows the integration of the whole city's district. According to the map, the highest integrated route is located between the outer ring and the inner cluster of the campus. Unfortunately, there is no GS building on that route. However, it appears that another high integration route is located on the route that links the most of the inner cluster buildings together. From the map, the whole area seems to well-connect. However, GS may consider occupying the building on the highest integrated route if they need to expand. In this direction, GS campus would be more compact, as well as GS can enhance interactions and can link the outer link and inner cluster together.

Sprint Campus: The Sprint campus is a much larger-scale campus than GS. It is also custom-designed campus. Compared to GS campus, even though the radar graph (Figure 3.12) also illustrates that the buildings distribute within the 800-meter radius and can be reached within 18 minutes of walking, the average distance between building and the average walking time between buildings are only 291 meters and less than 7 and a half minutes. These facts imply that Sprint campus is well organized and more compact in terms of spatial distribution. According to Table 3.02, the small numbers of standard deviation for average distance and walking times between buildings imply that all building in the campus cluster to each other as a whole group. This is an advantage of a custom-designed campus. In addition, it may illustrate that a custom-designed campus tends to use the land more effectively.

Contrary to the physical distribution of the buildings, the floor plate area and floor plate compactness ratio of the campus are more diverse. According to Table 3.02, most of the buildings have their floor plate area around 3,000 m^2 –4,500 m^2, except three buildings, Truman B, Eisenhower C, and Carver A. These buildings have floor plate areas of more than 6,000 m^2. In addition, the floor plate compactness ratio illustrates that all of the buildings in the campus have rectangular shaped floor plate, not the circle or square that are ideal froms for the floor plate of office building purposed by Allen (1997)

The axial map (Figure 3.14) illustrates that, including Disney A, Disney B, Disney C, Carver A, Eisenhower A, and Eisenhower B. The other high-integrated routes are the routes that connect the Truman buildings cluster and Disney buildings cluster, that are the clusters located at the center of the campus. These would suggest that people would tend to gather around the central area of the campus. On the contrary, the buildings located on the edge of the campus, such as carver B and Eisenhower C, or Earhart buildings clusters that are located on the northern side of the campus tend to be a segregated area. To combat this low integration, Sprint may use building function strategy, such as common area or canteen, to attract their staff to walk there.

Sun Campus: This is the smallest campus studied in this research. Obviously, as the radar graphs (Figure 3.15 and Figure 3.16) illustrate, the buildings in the campus locate within 300 meters radius and can be reached within 8 minutes of walking. In addition all buildings in the campus are arranged into a loop form, which left continuous open space at the core of the campus. The small and compact size of the campus is also reflected in the average distance and the average walking time, those are 101 meters and less than 4 minutes respectively (Table 3.03).

Table 3.03 also illustrates the narrow range of the floor plate area, ranging from 5,100 m^2 to 6,800 m^2. Most of the buildings have the floor plate size similar to each other, or around the average floor plate size (5,800 m^2). Compared to the GS and Sprint campuses, the average floor plate area of Sun is larger. Similar to the Sprint campus, the floor plate compactness ratio of the campus is not the ideal shape proposed by Allen (1997). Most of the buildings are rectangular shape, not a square or circle. The ratio of most buildings in the campus ranges from 2.5 to 3.5. However, BRM 01 building has a floor plate ratio 6.28, which is hugely different from the other.

Since the campus is very small, the axial map of the campus (Figure 3.17) may not be useful since it might generate too few axial lines. However, according to the map, the highest integrated route is the route that connects the buildings located on the southern side, including BRM 04, BRM 06, and BRM 07. On the other hand, the most segregated route appears at the northwest corner of the campus. The open space core has moderate integration. However, as mentioned earlier, since the campus is very small, the short walking time can play an important role to combat the segregated area.

TMS Campus: TMS workplace is very diverse in terms of spatial distribution since it consists of 12 on-campus buildings and 4 off-campus buildings. The spatial analysis in Chapter 3 divided TMS campus into two different scales, including (1) on-campus buildings only, and (2) all buildings, inside or outside campus.

The radar graph (Figure 3.18) clearly illustrate that one of the off-campus building, the Project Center building, is located separately from the rest. The average distance from other buildings to the Project Center building is around 11 kilometers, while the second farthest building in the TMS, Hamilton Place, has the average distance less than 4 kilometers (Table 3.04). Obviously, the location of Project Center building increases the average between building distance in the TMS campus. As Table 3.04 shows, the average distance between buildings is more than 2 kilometers. However, the average travel time between buildings is about 11 minutes, since the travel between on- campus buildings and off-campus buildings is assumed to be driving, not walking.

Focusing only on-campus buildings, the radar graph (Figure 3.19 and Figure 3.21), the on-campus buildings are located within a 900-meter radius, or within 18-minute walking. The farthest on-campus building is a vehicle building. And the rest are loosely clustered in the campus. If off-campus buildings are included, the TMS campus is the most dispersed campus among the 4 study sites.

The floor plate area of the buildings is also diverse, from 800 m^2. to nearly 12,000 m^2. However, the average floor plate area is around 4,000 m^2. The largest buildings are TMS Headquarters and the Project Center building. The building that has the smallest floor plate area is the Vehicle Services building.

Interestingly, while the floor plate compactness ratio of each building also diverse from building to building; half of the buildings in TMS campus have a floor plate area ratio less than 2. This implies that those buildings are close to the Allen's (1997) ideal floor shape for office space.

The axial line map (Figure 3.22) is computed based on on-campus buildings only. The main reason for excluding the off-campus building is because it is embedded in the urban fabric, and it is too far from the campus cluster, especially the Project Center building. For on-campus buildings, the highest integrated routes are the routes that run along the north-south axis and connect all of the buildings in the campus.

In summary, each campus has individual characteristic driven from spatial distributions. The custom-designed campus tends to have a more clustered layout, while the campuses that occupy the speculative office buildings in an existing urban fabric tend to be more disperse. The employees who work in a more dispersed campus will take more time to travel between buildings. However, as mentioned in Chapter 1, according to the New Urbanism approach, the optimal size of a neighborhood is with 5 minutes of walking (Becker, 2004). Only the Sun campus achieves that average walking time between buildings. Most of the corporate campuses, especially those of large corporation, tend to be a much larger size and the average walking time of those campuses is obviously more than a five minutes.

In each campus, are there any relation, or predictable trends, between (1) frequency of interaction and floor plate area, (2) frequency of interaction and floor plate compactness, and (3) frequency of between-building interaction in any building and locational factors of the building?

From Figure 3.23 to Figure 3.34, the scatter plots illustrate the cluster of interactions and the physical attributes of each campus. However, in summary, there is no obvious relationship of the interactions of employees and physical attributes of that campus.

For relation of floor plate area and interaction within the building, the graphs from each campus (Figure 3.23, Figure 3.26, figure 3.29, and figure 3.41) show that there is very low correlation of the relationship. Even though each graph illustrate clearly that interactions on the same floor aggregate as a cluster above the interaction on different floors cluster, both interactions show no significant relationship or clear direction on the floor place factor. However, in some campuses, the Pearson correlation (R) calculated is moderately high. For example, the R value between interaction on the same floor and floor plate in TMS campus is 0.65. But it may be a coincident because the result couldn't be found consistently across the same campus or for different campuses.

The same patterns are also found after investigation of the relation of floor plate compactness ratio and interactions. There is no related trend for those variables. Again, we can find some high correlation values in some of the campuses. But it is, obviously, inconsistent. In contrast with Allen's (1997) proposal, the compactness of floor plate size alone does not enhance or restrict interaction among employees.

For interaction between buildings, again, the results show no valid trend between the average travel time between buildings and average interaction frequency. The building that has shortest walking time, or is located nearest the center of the campus, doesn't necessarily have more frequent meetings than the building that is located off the center.

In the case of GS campus and Sprint campus, there is some relation of meeting frequency and integration. Buildings located or clustered near a high integration route tend to generate more frequency of interaction between buildings than buildings located far from the high integration route. However, the trend is not clear in the Sun Campus and TMS campus.

Do the actual travel time and the self-reported travel time correlate?

The Pearson correlation is computed to verify the relationship between estimated actual travel times, and self-reported travel time. From Figure 3.35 – Figure 3.38 illustrates that the patterns of both are very similar. In the Sprint and Sun campus, the largest fraction of staff tends to spend 15 minutes or less per week in walking to and from other buildings in the campus for meetings. The pattern is the same for both actual travel time and self-reported travel time. In the GS campus, even though the original data set used a different scale, the result is similar to those of the Sprint campus and the Sun campus. The GS's staff tends to spend less than and hour a week for walking to and walking back from meetings in other buildings in the campus.

For TMS campus, there is some discordance between actual travel time and self-reported travel time. The self-reported travel time for the TMS campus is the same pattern as the other campuses. The largest fraction of the TMS employees (48%) reported that they spend 15 minutes or less for traveling to meetings and traveling back. The actual travel time, however, suggests that the largest fraction (63%) of the staff spends more than an hour per week traveling to meeting. Considering that TMS campus is very dispersed, it is understandable that the fraction of people that spend more than hour a week in travel is higher (6% for self-reported travel time) than other campuses that are more compact.

While most of the graphs (Figure 3.35 – Figure 3.38) for every campus, except the line that represents TMS's actual travel time, reflect the Allen Curve (Allen, 1997), the Pearson Correlation values between actual travel time and self-reported travel time are moderate to weak, from 0.58 in Sprint campus to 0.43 in Sun Campus and TMS campus. The comparison results also suggest that the self-reported travel time tends to lower than the actual travel time. At this step, there is not enough evidence to clearly indicate whether it is the actual travel time estimated by this researcher that is over-estimated, or it is the self-reported travel time that is under-estimated by the respondents. In addition, from the travel time profile of each campus, it can be inferred that, for between building meetings, most of the employee either have a meeting in a building nearby or rarely have a meeting outside their own building. This inference is in accordance with previous study (Allen, 1997; Becker et. al, 2003).

In addition, the more compact or more clustered campus, such as Sprint and Sun, tend to encourage travel to meetings than less clustered campuses. The differences between two types of travel time are also less in smaller campuses than in dispersed campuses.

Are there any predictabed trends between actual travel time and between-building interaction?

A linear regression model was performed to estimate the trend of the relation between actual travel time and between-building interaction (please see Figure 3.39 to Figure 3.42). The results illustrate that, for all 4 campus, the interactions tend to reduce when actual travel time increases, as expected from the previous study (Allen, 1997; Becker et. al, 2003).

Considering the R square, which infers the influent of the predictive variable (travel time) on the response variable (interaction), it is obvious that there are some differences between the compact campus and the dispersed campus. In the compact campus, including Sprint and Sun, the influent of actual travel time on interaction prediction is 11 percent and 14.6 percent respectively. On the other hand, the influent of actual travel time in GS campus is just 1.7 percent, and only 1.6 percent for TMS campus. In addition, for TMS campus, since the p value is 0.126 (a more than significant level at 0.05), it also implies that the independent variable (travel time) in this case is incapable to predict the correct trend.

From the results, the relation of travel time and interactions in the compact campus might be easier to predict than for the more dispersed campus. With no precedent literature that studies the issue, more evidence is needed in future study.

Research limitations

There are two major limitations to this study, including data limitations and methodological limitation.

Data limitation

Using the IWSP's archival data has some advantages. The archival data selected was from large corporations and its size is large enough to perform meaningful statistical test. However, the data lacks some relevant information for this research, this is not surprising since it was not designed for this research, especially true for the data about informal interaction patterns of the respondents. The other data that might have been useful for this research is data about the area outside the building and the interaction happen outside the building.

Some inconsistencies in terms of different scale used in the questionnaires created some difficulty to recoding. Since the type of the question was the same, but the range of the scale differed from site to site. To make a comparison among study sites, some of the scales had to be recoded, which could create some inaccuracies.

The physical data for each site was collected mostly from Google Earth software. While it can be used to measure distances or compute the building area, the aerial pictures of the building are based on satellite images and might be distorted due to different angles when the aerial images are taken and combined together, especially the high rise buildings of GS campus. These problems can result in some errors in the measurement.

Methodological limitation

While it is useful to predict interaction, space syntax is suspected by some scholars for its subjective procedure for creating the axial line, which is the basic unit of the axial map (see Rotti, 2004). For this research, employing space syntax method may not fit the situation of the campus located within the city, or the campus for which it is difficult to identify its territorial boundaries, such as GS and TMS campus. On the other hand, for the small campus such as Sun, the calculation of the integration may not accurate since there is too few axial lines.

As mentioned earlier, Google Earth was used to measure physical attributes. This measurement can contain some human errors due to limitations of the software in zooming, or regenerating the image. The buildings and the distances are huge in reality, reducing this real scale to a display monitor and make measurements from that will obviously include some deviations.

Future research

To further investigate the relations of spatial attributes and interaction pattern in corporate workplace context, future study should include a wider variety of corporate campus, in term of size, dispersion, and locational factors.

The tools for measurement of the relationship should be further explored, especially more advanced statistical and database tools such as GIS, or spatial statistic. In addition, some advanced tools that can detect interactions or position, such as GPS could be useful to collect the data need.

The challenge for future research would also be to better understand the impact of physical attributes on interaction pattern. However, since the advancement in information technology (IT), the effect of the IT on both physical attribute and interaction should be included. The growing number of mobile workers is changing the idea of static, mono-functional physical workplace. Future study should concern the merging of the physical world and technology, and the relation between this hybrid space and interaction patterns.

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