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DEFINING AND EVALUATING AGILE CONSTRUCTION MANAGEMENT FOR REDUCING TIME DELAYS IN CONSTRUCTION

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by

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DEDICATION

谨以此文献给我亲爱的妻子，是她用爱鼓励、陪伴和支持我一路走过。

I lovingly dedicate this thesis to my wife, who supported me with encouragement and love every step of the way.

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ABSTRACT

Both competitive market forces and growing societal needs have triggered the demand for rapid delivery of construction projects, or at a minimum, for projects completed on schedule. However, schedule delays are common and recurring in construction, inevitably resulting in rework, cost overruns and legal claims. As projects become increasingly complicated, delays arise in a more unpredictable manner. The initial motivation for this research is to explore a systematic flexibility to deal with delays caused by complex changes in construction and meanwhile enhance the overall project performance. Accordingly, agile construction management is proposed in terms of a conceptual framework. Derived from agile theories in other engineering disciplines, agile management is an integrated method that allows projects thrive in a fluid environment by applying agile enablers (approaches) throughout the project lifecycle. Since agility and relevant theories are emerging in construction, the proposed agile ideas and enablers are verified by qualitative interviews with construction professionals. With ultimate goal of reducing delays, a case study is conducted investigating how much delays could be reduced if the agile enablers were used.

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CHAPTER 1. INTRODUCTION

1.1 Overview

A schedule is essential to the successful execution of construction projects, but completing projects on schedule is often hampered by inherent risk and uncertainty. Schedule delays are common and often cause considerable losses in addition to time overruns, such as cost, quality and safety issues. Current construction is characterized with increasing uncertainties, resulting in more unpredictable delays. This situation is partially due to the nature of design and construction processes, which contain dynamic interactions among diverse parameters, such as project attributes, participant experience, cost and site condition constraints (Lee et al., 2006). There is a need for a flexible mechanism to facilitate project management that is more adaptive to delays.

When it comes to flexibility, the theory of agile software development and relevant methods shed light on handling unforeseen customer requirements, which improves products in the long run. What is more, service-oriented production principles have triggered a series of agile manufacturing theories to deal with rapid changes for increasing customization. Inspired from these ideas, this thesis presents the idea of agile construction management in the form of a conceptual framework.

1.2 Background

Agility initially appeared in the mainstream literature in the 1990s (Goldman et al. 1991) and has become widely used across many fields and disciplines. It literally refers to the ability to deal with uncertainties effectively (Sharifi and Zhang 1999, Katayama and Bennet 1999).

Several ways are available to define this innovative concept. One comprehensive definition for agility is: “a persistent behavior or ability of a sensitive entity that exhibits flexibility to accommodate foreseen or unforeseen changes rapidly, follows the shortest time span, uses economical, simple and quality instruments in a dynamic environment and applies updated prior knowledge and experience to learn from the internal and external environment’’ Qumer and Henderson-Sellers (2006). For information system development (ISD), agility was defined by Conboy (2009) as “the continual readiness of an ISD method to rapidly or inherently create change, proactively or reactively embrace change, and learn from change while contributing to perceived customer value, through its collective components and relationships with its environment”.

As shown in Figure 1-1, agility appears as a composite concept beyond regular “flexibility” that incorporates the ideas of flexibility, responsiveness, adaptability and coordination under one roof (Dyer and Ericksen 2009).

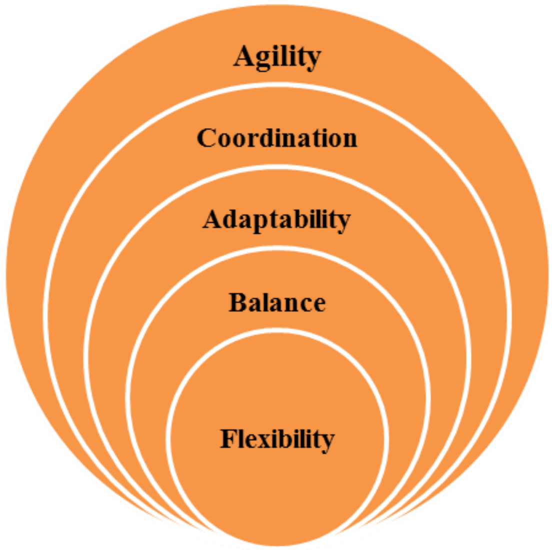

Figure 1-1. Conceptual layers of agility

In the engineering field, agility refers to the ability of a system to rapidly adapt to market and environmental changes in productive and cost-effective ways (Sharifi, et al. 2001). Accordingly, initial agile methods were developed based on principles mentioned above in the software development industry. In more complex interdisciplinary industries, standalone agile methods are inadequate to ensure coherent agile performance because of complicated organizations, longer development cycles and rigorous standard compliance (Stelzmann et al. 2010). Thus, a series of agile system strategies is required, and the manufacturing industry sets an example as agility had been substantially explored under the name of agile manufacturing.

1.3 Research Goals

Compared with manufacturing, which is a repeated and process-based activity, construction is more unique and project-based. Delay problems recur largely because of changes in the design, availability of resources, materials, information and site access.

This makes maintaining an up-to-date work plan very difficult and plans rarely reflects the actual sequence in which tasks are completed. Consequently, it is more than necessary to find a systematic flexibility to allow projects to thrive in such a fluid environment. Agile construction management is considered appropriate by the author for this task. Considering agility is still an emerging concept in construction, this research aims to explore agile construction management in two steps:

First, the feasibility of agile ideas will be analyzed conceptually by the review of existing literature on this topic. The result of this step is a framework for agile construction management in which proposed agile enablers can resolve delay problems as well as enhancing overall project performance.

Secondly, the research focuses on validating the proposed agile enablers in terms of qualitative interviews and case studies. The interviews and case studies further refine the results from both qualitative and quantitative perspectives.

CHAPTER 2 DEFINING AGILE CONSTRUCTION MANAGEMENT

2.1 Introduction

Schedule delays are common on construction projects, which can negatively impact the overall project performance since delays are usually accompanied by other problems such as cost, quality and safety issues. In an attempt to try to manage delays, researchers have studied the root causes of construction delays in certain geographical areas or for certain types of projects. By ranking the occurrence probability of these delay factors, these studies provided construction professionals with a guideline in preventing similar delays from happening in future work. Other research has focused on how to present delays in the context of the schedule impact, and determining the influence of delay events and related liability of project participants.

In spite of these achievements in analyzing delays, there remains a problem of consistent and significant delays on construction projects. Solutions to delay problems are still the responsibility of the project manager, who mostly relies on past experience and standard planning and scheduling solutions. As project complexity continues to increase, this experiential approach will be insufficient. The complexity of construction projects and delay causes requires an integrated approach to solve this problem. There are only so many potential delays that can be foreseen and planned for at the start of a project. For unforeseen delays, there is a need to introduce flexibility into the project to minimize the risk of schedule delays. What is more, this flexible mechanism should not only benefit scheduling but also facilitate the improvement of overall project performance.

Based on extensive literature review, agility and agile development principles could provide a solid basis for handling uncertainty in construction delays. These principles have been proven through successful application in other engineering disciplines. With the ultimate goal of reducing delays in construction, an agile construction management system is proposed in the form of an explanatory framework.

2.2 Background

2.2.1 Delay-related Research in Construction

Completing large construction projects on time is challenging since delays can occur for various reasons. Among these reasons, however, it is difficult to identify the uniform root causes, which could vary depending on different project environments. Assaf and Al-Hejji (2006) concluded that a critical delay cause recognized by construction project parties in Saudi Arabia is change orders. Other issues such as building permit approval, inspection, changes to laws and regulations have been identified as major delay causes for construction projects in Florida (Ahmed et al. 2003). Faridi and El-Sayegh (2006) addressed the top-ten delay causes in the UAE construction industry, such as preparation and approval of drawings, inadequate pre-planning, and slow decision making for owners.

These delay causes were primarily obtained based on qualitative surveys conducted among industry professionals. Additional results given by this type of study would be a ranking of importance of associated delay factors. A review of literature has identified major delay factors (Odeh and Battaineh 2001, Lo et al. 2006, Sambasivan and Soon

2007, Luu, et al. 2009) which can be further grouped into eight categories as shown in Table 2-1.

Table 2-1. Construction delay factors and related examples

Delay Factor	Example
Project-related	Short contract duration, Legal disputes, Type of contract, Type of bidding
Owner(consultant)-related	Delays in payment, Change orders, Late in approving documents, Poor coordination
Contractor-related	Difficulty in financing project, Rework due to errors, Conflict with subs, Ineffective planning
Designer-related	Mistakes in design documents, Lack of constructability, Inadequate experience
Labor-related	Labor shortage, Unqualified workforce, Low productivity level of labors
Material-related	Material shortage, Delay in delivery, Damage of materials, Late procurement
Equipment-related	Equipment breakdowns, Shortage, Low productivity
External environment-related	Delay in obtaining permits, Weather issues, Safety accident, Traffic restriction, Change in Government rules, Unavailability of utilities

Construction delays can also be classified to reflect the responsibility for delay events. The term non-excusable delay is used to describe time overruns due to contractors' mistakes. Excusable delays consisting of non-compensable and compensable ones distinguish delay responsibility caused by owner or owner's agents, and incidents beyond the control of both the owner and contractor, as explained by Hamzah et al. (2011).

To facilitate resolving disputes in delay claims, another type of analysis was developed, called delay analysis techniques, such as collapse but-for (CBF) technique, time impact technique, windows technique and isolated delay type (IDT) technique (Hegazy and Zhang 2005, Mohan and Al-Gahtani 2006, Yang and Kao 2009). One goal of these techniques is to identify delay duration by looking backward on schedule performance and comparing the as-planned, adjusted with as-built schedules. Another purpose includes determining the impact of delay events and related liability for each project party. But the research mentioned above mainly answers the questions on why delays occurred and how delays can be identified instead of looking into ways to reduce them.

When it comes to delay reduction in construction, relevant research findings are sporadic. By investigating practitioners' perception of delay reduction, Lo et al. (2006) assessed some mitigation methods provided by the construction industry review committee in Hong Kong. Hastak et al. (2008) summarized delay-reduction methods from professional documents provided by the Construction Industry Institute (CII) and broad survey investigations. The results are categories of forty-six schedule reduction techniques, thirteen management techniques and eleven CII best practices which can be used selectively for reducing project cycle time as well as improving project performance.

Other research was undertaken to reduce construction delays indirectly. Based on concurrent engineering principles, Bogus et al. (2005) suggested reducing project delivery time through overlapping design and construction activities. In addition, given the increased uncertainties during overlapping processes, overlapping strategies such as overdesign, standardization and set-based design, etc. were developed to mitigate the risks of rework (Bogus et. al. 2006). Other studies addressed change management strategies to mitigate delays caused by unexpected changes (Lee et al. 2005, Motawa et al. 2007).

Also, delays could be reduced indirectly by adding appropriate contingency to original activity durations. Park and Peña-Mora (2004) proposed a reliability buffer model where a schedule buffer is located at the beginning of successor activities as pre-checking processes to detect and settle potential uncertainties coming from preceding activities, to absorb recurring delays. Another way of reducing delay is to predict delays with a proposed model of Bayesian belief networks (BBNs) based on the causal-relationship between delays and delay causes. The probabilities of certain delay occurrences were validated in two case studies (Luu, et al. 2009). Even though some types of sensitive delays were pre-identified, the authors pointed out that the proposed approach is still too general to be applied to arbitrary projects.

Construction is a project-based activity where every project has a unique environment. A real challenge to reduce delays is to cope with time overruns caused by unexpected changes. If changes are inevitable, the only sensible path left is to manage and direct them in a flexible manner. Accordingly, with respect to fluid construction jobsites, the initial motivation of the study is to pursue a systematic flexibility which not only minimizes the overall risk of uncertainty but also enhances relevant project performance. Agility and related ideas are presented as a possible approach consistent with this goal.

2.2.2 Overview of Agility Application

2.2.2.1 Initial Application of Agility

This concept of agility was initially utilized and valued in computer software-development industries. Based on the publication of the Agile Manifesto (Beck et al. 2001), some agile methods such as Extreme Programming (Beck 1999), SCRUM (Schwaber 2004), Crystal (Cockburn 2004) and Feature Driven Development (Palmer and Felsing 2002) were developed highlighting self-organization, collaboration, and process adaptability throughout the project life-cycle. Focusing on how to respond to changes, these methods encourage positive reaction toward changes by allowing incremental planning and increased customer involvement, and anticipating changes for subsequent learning experience (Abrahamsson et al. 2002).

2.2.2.2 Agile Manufacturing and Agile Management

In manufacturing, service-oriented production principles require adaptive and flexible management systems to deal with rapid changes for increasing customized products. Noor et al. (2008) addressed that integrating agile methods into product lines increases customer satisfaction and shortens lead time to market with the core value of collaborative planning, execution and high customer involvement.

As a result, increasing use of agility-related methods in manufacturing bred the idea of agile manufacturing, which was defined as the capability of surviving and improving in a competitive environment of continuous and unpredictable changes by reacting quickly and effectively, driven by customer-oriented products and services (Jin-Hai et al. 2003, Dowlatshahi and Cao 2005). The agile enterprise, as an extension of agile manufacturing application, describes an organization that utilizes agile principles to achieve success (Dyer and Ericksen 2009).

Compared to traditional management principles, agile principles can be distinguished based on different aspects as shown in Table 2-2 (Owen et al. 2006). Traditional project management can be somewhat ineffective because it is more likely to suffer changes with a sequential workflow which is barely revisited. In contrast, agile management is a highly iterative and incremental process, allowing a project team to constantly evaluate the evolving product and obtain immediate feedback from users or stakeholders. The team learns and improves the product, as well as their working methods, from each successive cycle (Hass 2007).

Table 2-2. Comparison of agile and traditional management

	Agile	**Traditional**
Attitude to change	Embrace change	Control/avoid change
Approach to risks	Proactive adaptation	Reactive
Management structure	Flat and team-based	Close and hierarchical
Attitude to customer involvement	Key to organization leaning	Irritating obstruction
Nature of planning	Delayed decision on planning	Sequential and comprehensive

In a rapidly changing market, large-scale design and production systems running under a central-control and distributed-operation environment are more likely to suffer project overruns. Any external turbulence or internal uncertainty can easily put product delivery behind schedule due to the complex and rigid information exchange process between control and operation units. Relevant "ripple effects" above and beyond-the-time delay like scope and cost issues generate a requirement for a systematic solution to delay problems. Agile principles mentioned above were further evolved into agility-related strategies, covering technologies, people, information systems and business processes (Kharbanda 2008).

One attribute for the agile strategy is to increase the flexibility and responsiveness of shop floor operation by integrating process planning and production control. Accordingly, software-based artificial intelligence systems such as the multi-agent system (MAS) (Lim and Zhang 2004), fractal manufacturing system (FrMS) (Ryu et al. 2003) and holonic manufacturing system (HMS) (Colombo et al. 2006) were developed to achieve agility in manufacturing. The system has cross-functional agents of different working stations which are designed to run their jobs autonomously for individual goals, and cooperate with each other to achieve global goals efficiently (Wang et al. 2007). Although MAS, FrMS and HMS have different priorities in operational principles, they share a critical common point in emphasizing a system built on autonomous and collaborative modules that are capable of self-organizing and conducting adaptive behavior through information-exchange in a changing environment.

Inspired from the adaptive biological evolution process, Tang et al. (2011) simulated the production system as a living organism where control and regulation stations run as "neuron" and "hormone" respectively. The key for this bionic manufacturing system lies in synchronizing "neuron" control and "hormone" regulation activities excels traditional regulation mechanism of sequential information-exchange in providing more system efficiency for faster response to unexpected changes occurred during design and production process.

2.2.3 Agility in Construction

The manufacturing industry has seen dramatic improvements in productivity, while reducing lead times and costs. However, the construction industry has not seen such positive results though it carries many similarities to manufacturing in managing complex operations, as well as a rapidly changing market and dynamic customer requirements. Improvement opportunities are in demand. Accordingly, some research efforts have been taken in this aspect. For example, lean construction, inspired from the lean production ideas appeared to improve the overall construction productivity through the continuous working process of eliminating waste. Agility, another underlying theory thriving in manufacturing is still emerging in construction. In construction literature, agility was usually mentioned together with leanness, as lean-agile paradigms (Naylor et al. 1999).

A "leagile" concept was addressed in terms of a lean and agile production system for mechanical and electrical construction. Agile dimension provides flexibility of customer requirements and trade teams' needs at various stages of construction (Court et al. 2006, Court et al. 2009). Moreover, Lu et al. 2011 proposed a lean-agile model of homebuilders' production systems where agility part is used to respond to fluctuating market demands. One common point of these studies is the agile dimension is linked to the lean dimension by a "decoupling point" to synchronize both responsiveness to volatile demands and the production system.

Other studies assessed the possibility of engaging agility in construction management. Owen and Koskela (2006) reviewed the strength of agile manufacturing before arguing the construction industry might potentially benefit from agile project management because of proactive response to unpredictable changes. Owen et al. (2006) addressed that Agile Project Management (APM) might be tentatively appropriate for the design phase of construction which contains more customer involvement, conflicting requirements and constant trade-offs because APM allows for the embracing of changes for continuous improvement, a creative solution particularly for complex requirements. Furthermore, the concept of Agile Construction was proposed recently by Daneshgari (2010), characterized with responsiveness and adaptation to unexpected changes.

2.2.4 Possible Research Potential

To deal with complex delay issues, existing literature results associated with delay causes identification and delay analysis techniques seem reactive instead of proactive. Complex delays require a systematic thinking in a "big picture" that enhances the entire project performance. Especially for those unpredictable delays, there is a research gap in providing an integrated method characterized with agility as a proactive alternative to mitigating delays. What is more, even though the theory of agile project management and agile construction have been mentioned in construction-related studies, the effort is still sporadic and addresses general discussion on whether agility is suited to optimize the overall project performance in construction. As a result, agile ideas are rarely used in dealing with a specific construction issue. Therefore, there is a need to formalize this concept through a framework of an agile construction management system focusing on reducing schedule delays.

2.3 Methodology

2.3.1 Overview of Research Method

In order to create a framework for agile construction management, a comprehensive review of existing literature is employed as the primary approach. The literature review covered the area of agile construction management as well as agility in software development and manufacturing. Since agility encompasses multiple meanings and principles, the first task was to provide a clear and specialized explanation for what agility means in construction and to propose an agile management framework so as to eliminate ambiguity.

Given that the concept of agile management is still emerging in construction, a conceptual framework is considered appropriate as a type of intermediate theory that attempts to connect all aspects of research interest. Thus, reducing delays can be more like a "problem solving process" which starts from "problem identification" (delay causes), "solution development" (theoretical/empirical data and practice) to "result evaluation" and "lessons learned" (validation of delay-reducing methods). Also, the proposed framework acts as a map that gives coherence to all "milestones" during the process of delay-reduction.

2.3.2 Agile Framework in Manufacturing

Numerous research efforts have been undertaken on developing conceptual models of agility or agile manufacturing. Sharifi and Zhang (1999) presented a conceptual model which divides the application of agility into three elements: agility drivers, agility capabilities and agility providers. In this model, agility capabilities such as responsiveness, competency and flexibility can be achieved through agility providers so as to deal with agility drivers in terms of external changes. This conceptual model was then refined particularly for agile manufacturing. Ramasesh et al. (2001) addressed a conceptual framework on how an agile manufacturing system is constructed by components of unanticipated changes, agility attributes and agility-based capabilities. More conceptual models of agile manufacturing proposed by Vázquez-Bustelo and Avella (2006), Lin et al. (2006) specified detailed factors and methods for either agility capabilities or enablers.

2.3.3 Agile Framework as Method

Accordingly, an agile construction management framework, as the primary analysis means in this study is developed with components focusing on mitigating schedule delays in construction. Moreover, the proposed framework attempts to outline possible resources related to agility, and draw up logical procedures to be agile in project management. Each framework component is explained in detail, thus increasing awareness for pursing agility in construction management. Meanwhile, some framework components are expected to serve as a guideline for construction professionals to cope with uncertainty-related delays in practice.

2.4. Results

2.4.1 Framework Overview

In order to accomplish agility in dealing with construction delays, an agile construction management framework is proposed as shown in Figure 2-1. In general, the framework is designed to bear three functions. First, the framework presents a path to pursue agility in a cause-effect manner. Second, the framework suggests methods (also known as “agility enablers”) to become agile. Third, the framework provides a path to validate the proposed agile ideas, including all framework components. When building components for the agile framework, this study particularly refers to existing results from agile manufacturing. Manufacturing has set an example for construction because of its dramatic improvements in productivity and in-depth customization. If each construction site is considered as a “temporary production line”, the highly “standard production” may turn out to be the future trend of construction. Therefore, ideas inspired from agile manufacturing are incorporated in developing agility in construction.

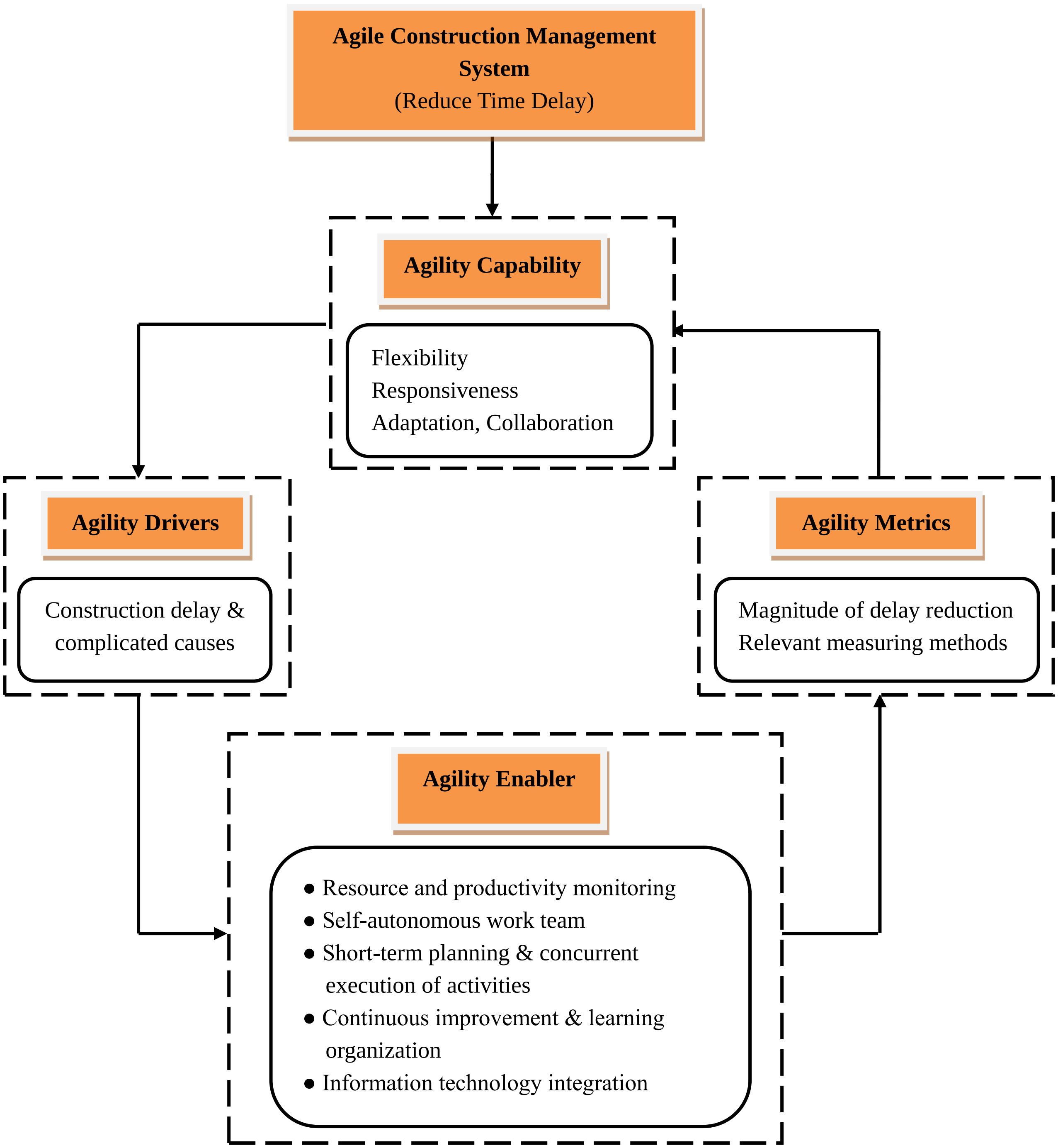

Figure 2-1. The framework of an agile construction management system

2.4.2 Component Analysis

2.4.2.1 Agile Construction Management System

Being agile cannot be attained overnight. Instead, it is a highly iterative and incremental process which is referred to as an agile construction management system in this study. Recurring delays in construction create a demand for developing systematic strategies. In this case, agility is recognized as a competitive advantage to better cope with increased uncertainties. The agile management system can act as a guideline for innovative construction companies to refer to in adopting agile practices.

Agile management implies a "two way" process to responding to "changes" that could cause delay problems. In construction for example, each phase throughout the project delivery process is incorporated into an agile construction management system. Faced with "negative changes" resulting in delays, each phase in the system focuses on mitigating the ripple effects of delay events. In other words, individual delays should be handled in a controllable scope to prevent them from being expanded. On the other hand, all phases in the agile system should interact with each other to share "positive changes" that could bring time-savings. Thus, the overall delay can be mitigated indirectly by absorbing any period of time saved by each individual phase.

Agile project management delivers a strategy to deal with complex and uncertain delays. Variability associated with unexpected changes is viewed more positively as a "learning opportunity" for long term self-improvement. At the project level, the agile system should provide construction professionals with specific agile methods to manage unforeseen project delays. The best solutions would be those offering the "best value" after balancing the trade-offs between time and other relevant project goals. At the enterprise level, the agile management system implies criteria consisting of agile methods which should be implemented widely from the project planning, execution, and every step of the decision-making process until it finally becomes a core competence for the enterprise in an increasingly competitive market.

2.4.2.2 Agility Capability

Agility capability generalizes the ultimate attributes to be achieved for being agile. Unlike a simple term interpretation, defining agility is more like a brainstormed process to develop a pool of associated ideas, as applicable. Many research efforts have been undertaken in this aspect, and the major results are summarized in Table 2-3.

Table 2-3. The attribute of agility and agile organization

Article	***Flexibility***	***Responsiveness***	***Adaptation***	***Self-direct***	***Collaboration***
Yusuf, Y.Y. et al. (1999)	√				√
Ramasesh, et al. (2001)	√	√	√		√
Devadasan, et al. (2005)	√	√	√	√	
Vázquez-Bustelo and Avella (2006)	√			√	√
Lin, et al. (2006)	√	√			
Tsai, et al. (2008)	√	√	√		

According to Table 2-3, flexibility is undoubtedly the basic value of agility. Responsiveness and adaptation are selected as other two most typical characteristics in conjunction with flexibility. In running specific project activities, agility highlights both a self-motivated and collaborative working atmosphere. Empowered working teams are formed to run jobs more positively while being less disrupted by over-control or micro-management. Meanwhile, they can be allocated flexibly to work together in case of urgent tasks, which can form long-term “partnership” for the enterprise-level strategy.

One attribute of agility distinguished beyond regular “flexibility” lies in “embracing changes” which can be explained as anticipating changes and learning from changes. In other words, traditional adaptation to changes means an entity attempts to adjust itself passively when changes occur. Change is the driving force while an entity’s action is only a result of that force. Instead, “embracing changes” expects the entity to take advantage of changes to place itself in a better position. Embracing implies a two-way process where the entity not only responds to changes but can also influence them.

Construction projects can also benefit from this characteristic. For example, designers are supposed to “welcome” inputs of change from owners and contractors when all participants can obtain a better understanding of design and improve their own work continuously. This can reduce change orders that arise later in construction. As a result, delay events associated with designer’s changes could be reduced. If a construction project is labeled as agile construction management, the rest of the agile attributes such as self-direct, collaboration and partnership etc. should be applicable in other phases of the project delivery process.

2.4.2.3 Agility Drivers

In software development and manufacturing industries, agility and relevant ideas were initially addressed to respond to changing requirements on customization. Dynamic "changes" become the original incentive of agile management principles. In construction, "changes" in all project phases also exist, and inevitably disturb the as-planned schedules when delays arise. The motivation to accomplish agility in this study focuses on reducing, or at least mitigating time delays.

In a standard production process, agility might be considered contradictory with the intention of time reduction since agility requirements can increase the system variability by allowing more changes. However, construction is different in that it is a project-based activity and each project inherently includes various uncertainties. In this case, agility is better suited for dealing with delays caused by complicated reasons.

If delays consist of expected delays and unexpected delays, we need to work on them separately. Literature results including identification of delay causes and delay analysis techniques are more appropriate to deal with expected delays based on the empirical data and practice. Agile ideas are proposed to work on both delay scenarios. Especially, the unexpected delay which becomes a "pronoun" for uncertain changes in this study is the primary driver in pursuing agility in construction.

2.4.2.4 Agility Enablers

Agility enablers literally refer to a series of methods which can bring agile performance during the project delivery process. Also, agile enablers bear a function to alleviate time delays, in particular. Given that schedule performance is integral to project objectives, delay prevention requires a systematic effort throughout the project. In this case, the agile manufacturing industry provides a good example in applying agility to production management. Numerous agile enablers have been developed in terms of people (organization), technology, activity execution and enterprise level strategies. Many of them are applicable for construction when each project is considered as a temporary production line.

For agile manufacturing, Gehani (1995) addressed “six actions” required for the implementation of agile strategies, including cross-functional team sharing, empowerment for decision making, technology integration, delayed design specification, product succession planning, and enterprise-wide integration of learning. Additionally, more agile methods were proposed, such as self-autonomous and integrated teams, concurrent engineering, partnership in supply chain management, learning organization, and virtual organization, to indicate agility is also desirable as a long-term strategy for enterprises (Li et al. 2003, Devadasan et al. 2005, Vázquez-Bustelo and Avella 2006, Lin et al. 2006).

In construction literature, some studies initiated flexibility-oriented approaches to complicated project requirements. As mentioned in the background review of delay-reducing research, results such as concurrent design and construction (Bogus et al. 2005), reliability buffering model (Park and Peña-Mora 2004), dynamic change management model (Lee et al. 2005, Motawa et al. 2007) and the analysis of stochastic activity duration (Nassar et al. 2005, Kim and Reinschmidt 2010, König 2011), all have potential in instilling flexibility to construction from different research perspectives. What is more, early involvement of suppliers and long-term partnership with suppliers help projects stay agile in supply chain management since proactive and stable supply chains are more capable of absorbing procurement disruptions (Hatmoko and Scott 2010; Meng, 2012).

In practice, the construction inherently possesses a certain degree of flexibility as owners' requirements or rules and regulations change. Most approaches to flexibility are reactive, such as change orders and as-built plans. Other practice, like short-term planning may work but are still inadequate to deal with increasing job complexity. In addition, some project delivery systems such as fast-track, phased construction, Design-Build and Job Order Contracting are thought to inject certain flexibility to projects with the higher level of management authority. Last but not least, the development of information technologies such as computer-aid design tools, project management software, Building Information Modeling (BIM) have been changing the way of delivering construction project to be more flexible.

In this study, agile enablers inspired from the literature of agile manufacturing and flexible construction practices are grouped into five categories and presented in Table 2-4. Furthermore, sorted by the relevance to delay-reduction, the list of enablers in Table 2-4 is narrowed down to the "top-five" agility enablers described in the following paragraphs. Possible delay reduction by using the specified enabler depends on two criteria: On the one hand, the enabler could reduce delays directly by adapting to unexpected changes that may result in delays. On the other hand, delays could be reduced indirectly by using the enabler that could offset associated time overruns for shortening overall project delivery time. The potential to reduce delays is explained in the description of the "top-five" enablers as follow.

Table 2-4. Possible agile enablers for construction management

Strategy	Generic Practice	People	Technology	Theoretical Model
● Partnership with suppliers and clients ● Global supply chain management ● Enterprise Resource Planning (ERP) ● Early involvement of design/construction ● Concurrent execution of activities ● Learning organization ● Virtual enterprise	● Detailed backup plans ● Short-term plans ● Certain delayed design ● Just-In-Time Purchase (Least idle investment) ● Project delivery system (Design-build, Job order contract)	● Cross-functional team ● Empowerment for decision making ● Self-autonomous & integrated team ● Individual/team innovation ● Team training & education	● Computer Aid Design (Auto CAD) ● Project management software ● Data system integration (BIM)	● Concurrent design and construction ● Stochastic activity duration analysis ● Reliability buffering model ● Dynamic change management model

Real time resource monitoring and productivity measurement: If delays are generally caused by changes to original plans, agile construction management emphasizes the responsiveness to changes which is to figure out the time (i.e., time to detect and time to react to changes) taken to deal with changing scenarios. The longer it takes to identify a problem, the less time is available to formulate an appropriate response. Agile construction management focuses on shortening the time to detect the unexpected changes by monitoring resource usage with field feedback. For adaptation to changes, agile construction management highlights knowing the productivity as well as a thorough understanding of resource usage. Only if project managers know exactly how much time and resources it will take for the work to be completed can they determine more accurate plans to make up the time lost by delays.

Self-autonomous work teams with multi-functional crews: In order to get quick response to unexpected changes, agile work teams should be organized as self-motivated and empowered cells. Project manager as a leader but not taskmaster should facilitate agile teams to continuously adapt to improve their methods as they incorporate lessons learned from the previous cycle into the next iteration. In addition, agile work teams should consist of multi-functional crews, which can largely save time for deploying people from other teams in case of unforeseen tasks.

Short-term planning along with concurrent execution of activities: Short-term planning is considered as one of best methods to maintain flexibility in a highly-fluid construction site. Frequent review of original plans can keep all project participants in communication with each other. Timely adjustment to plans can effectively diminish the risks of time delay due to unexpected events. In addition, delay is usually related to a productivity issue in terms of idle time and resource waste. Thus, overlapping independent construction activities can effectively reduce this waste of time for creating a flexible, efficient and streamlined work flow.

Continuous improvement based on learning organization: Agile management emphasizes learning from changes, which is an enterprise-level strategy. This learning is a collaborative process with all project stakeholders actively working together to capture constant feedback, and learning lessons from the previous iteration. An iterative process of planning, changing, evaluating, and learning can drive agile work teams to improve the entire performance. Consequently, it makes teams more responsive to changes and less sensitive to associated negative impacts.

Information technology integration: Fluent project execution is built on smooth communication between all project entities. Following this logic, the communication can be more agile as inputs from different parties are integrated to one interface. Accordingly, the emerging Building Information Modeling (BIM) technology is conceived of as a platform for managing change and coordinating all project information. BIM literally allows more flexible information sharing and performs efficiency calculations on "what-if" scenarios, which indirectly reduces delays due to misunderstanding and ineffective communication of tasks and objectives.

2.4.2.5 Agility Metrics

Agility, as a fairly new concept in construction could bring challenges in understanding how it handles changes, and protects time schedules from being interrupted by uncertainties. It raises an important question on metrics to measure the effectiveness of being agile. Manufacturing has been found leading in this aspect for its successful experience in agile manufacturing. In order to measure agility, it is difficult to find a uniform metric for agility itself. Instead, performance measurement, as a process of converting effectiveness and efficiency of different dimensions to reasonable symbols to report, has been found appropriate for this task.

Within the agile enterprise, intensity levels of agility became the major metric assessed by agility indexes (Yusuf et al. 2001, Van Hoek et al. 2001). Based on the analytic hierarchical process (AHP) logical concept, Ren et al. (2000) applied a pairwise comparison technique to evaluate agility capabilities. Moreover, Fuzzy agility index (FAI) was proposed based on fuzzy logic theories so as to weaken the ambiguity in linguistic evaluation (Lin et al. 2006, Vinodh et al. 2010). Using Quality Function Deployment (QFD) methods, Tsai et al. (2008) integrated agility drivers, capabilities and providers into a relationship matrix and evaluate them with fuzzy numbers.

For the construction industry, the agility metric needs to be more specifically associated with delay-reduction, which means the magnitude of delay duration can be reduced for impacted project activities if agility enablers are used. Based on pre-determined metrics, agility could be evaluated in two steps. The first step is qualitative, where a survey or interviews would be conducted among relevant experts to collect professional opinions on target topics. The follow-up would be a quantative analysis focusing on how to convert the linguistic data to numerical and comparable results. The major quantative approaches include Agility Index Method (Yusuf et al. 2001), importance ranking methods based on AHP model (Ren et al. 2000), and FAI Method (Lin, et al. 2006).

2.5 Discussion

Construction is usually challenged to complete projects on schedule. In order to deal with increasingly complex delays, this study shifts the original idea of getting rid of delays to reducing or neutralizing delays by adding “agility” to the entire project management. Agility, a concept originating from agile manufacturing and other engineering areas, is found to be well-suited to construction management because of its potential to break barriers of "over control" and facilitate a flexible, responsive, collaborative and solutions-oriented construction delivery process.

Going beyond flexibility which deals with fragmented activity changes, being agile means a project is treated as an integrated system and its components are able to interact with each other against all kinds of uncertainties. Accordingly, agile construction management as a conceptual framework is defined in Chapter 2. Some components in the proposed agile framework like agility drivers and agility enablers are expected to offer guidance for practitioners to prepare for unexpected delay events. Though no single set of enablers can reflect all aspects, the key is to understand the relationships between the enablers, to deploy and integrate them, and finally to transform them into competitive capabilities. Chapter 3 begins this process by evaluating a select set of enablers for construction projects.

From the conceptual perspective, this study intends to create awareness of agility in construction management. For delay events that are inevitable, we need to come up with ways to manage them in a controllable way. Agile management could be appreciated not because it brings an innovative concept of handling uncertainties flexibly but because it represents a positive thinking, a mind shift. In dealing with uncertainties, we should learn from changes, grow from learning instead of struggling and complaining. We have to admit that agile principles are still vague for lacking of solid practice guideline. But the biggest credit agile management should deserve is its attempt to alter the way of thinking to change.

Last but not least, agile principles have been partially applied by some innovative construction companies (Daneshgari 2010) on certain construction stages such as the design phase and operation management. In order to convince more people that being agile is a valuable trait to enhance project performance, more research is needed.

CHAPTER 3 EVALUATION OF AGILE ENABLERS IN CONSTRUCTION

3.1 Introduction

Agile construction management is proposed as a possible managerial idea to deal with complex delays in construction. The introduction of this idea was explained explicitly in terms of a conceptual framework in Chapter 2. One critical component of the framework, the agile enabler, looks into possible methods to achieve agile performance throughout project management. Among all proposed enablers, this study identifies five of them that are better suited for being applied to construction. They were pulled out from both other agile engineering disciplines like agile manufacturing, and existing construction-related theories and practice which could have potential as driving force to promote agility ideas. These five enablers are:

- Real time resource monitoring and productivity measurement.
- Self-autonomous work teams with multi-functional crews.
- Short-term planning along with concurrent execution of activities.
- Continuous improvement based on learning organization.
- Information technology integration.

The research that created the agile framework in Chapter 2 was constrained because it primarily focused on the review of previous literature in which the findings could be limited by the subjective bias of relevant researchers. In this chapter, the study continues the work of verifying the five agile enablers by assessing their potential application in enhancing overall project performance as well as delay reduction in construction. Qualitative interviews with construction professionals were employed as the primary method for this task. Also, a case study in the form of a questionnaire about actual project delays was conducted to quantitatively investigate the effectiveness of delay reduction contributed by each agile enabler. The overall results are expected to result in meaningful, exploratory conclusions to guide future research on promoting agility in construction.

3.2 Background

3.2.1 Overview of Proposed Agile Enablers

Agile construction management is an approach to managing projects that allows the project to thrive under continuous and unpredictable changes. When compared to traditional and lean construction management as presented in Chapter 2, agile management has three major attributes: 1) It encourages both proactive and reactive responses to upcoming changes; 2) It requires highly cooperative, flat and self-motivated working structures instead of very hierarchical and sequential structures; 3) It is a repetitive and incremental process based on continuous learning and improving rather than a fast and streamlined process.

Based on the criteria of the three attributes, five key agile enablers mentioned above are proposed for targeting delays caused by uncertain changes, and ultimately improving overall project performance.

3.2.2 Resource Monitoring and Productivity Measurement

It has been found that unexpected change is one of the main causes for schedule overruns to become prevalent in construction projects (Lee et al., 2006). For responsiveness to changes, keeping daily records of how much material and labor hours have been invested works effectively in shortening the time to detect unexpected changes. Continuous recording of productivity, on the other hand, helps projects adapt to changes by tracking the variance of productivity regularly trending to track productivity variance by statistical analysis, suggested by Daneshgari (2010).

In construction, resource monitoring has been implemented as a part of work in the earned value method (EVM), a common project control technique to provide a quantitative forecasting of schedule performance. EVM can be improved when resource usage data is fitted to the Weibull distribution and then is analyzed probabilistically along with the risks involved (Nassar et al., 2005). As for productivity evaluation, Choi and Minchin (2006) measured the fluctuation of a project's daily productivity and identified factors that negatively affected the daily productivity. Computer-based simulation incorporating the effects of various interference factors that may occur during construction is another method to estimate an average measure of productivity (Choi, 2011). One primary advantage of the measurement is that it provides management with accurate feedback for project performance in advance, which supports better response to unforeseen issues.

3.2.3 Self-autonomous and Multi-functional Work Teams

Being agile should be reflected in structuring the team organization. Breaking down traditional hierarchies into flat structures can give construction crews a certain level of freedom to make their own decisions on project changes. Concurrently, individual workers with multi-functional skills will accommodate more flexibility for changing work assignments to address tasks, if needed.

This idea was derived from agile manufacturing in terms of multi-agent systems (MAS) where cross-functional agents standing for different working stations are distributed throughout the entire manufacturing process. The key to being agile in MAS is that these agents are designed to run their jobs autonomously for individual goals, and cooperate with each other to achieve global goals efficiently (Lim and Zhang, 2004; Wang et al., 2007). Actually, similar ideas were also suggested in research related to the construction supply chain. Xue et al. (2004) proposed a multi-agent based system in which all project entities are delegated a corresponding agent and work as a whole for more efficient supply chain coordination. Based on negotiation and utility theories, this system proved to support the decision-making in case of coordinating issues during supply chain operation (Lin & He, 2011).

3.2.4 Short-term Planning with Concurrent Activity Execution

Short-interval planning (e.g., regular review of schedule looking two weeks ahead) is a common and critical means for contractors to mobilize projects smoothly. Pappas et al. (2003) argued that poor construction productivity is commonly caused by a lack of resources at the crew level. Providing resources properly is a planning issue and short-interval planning facilitates just-in-time resource supply, thereby reducing possible delays and improving productivity (Pappas et al., 2003).

In addition, contractors live by the schedule. One goal of schedule review is to pursue concurrent work by performing as many activities as possible. Besides speeding up overall project delivery (Bogus et al., 2005), overlapping sequential activities actually tries to instill certain flexibility in the process. Because the process of adjusting the sequence of activities is supposed to bring management deeper understanding of the project complexity, which is a factor that increases the ability to be flexible, as explained by Walker and Shen (2002).

3.2.5 Continuous Improvement based on Learning Organization

Continuous improvement is not new in construction and is emphasized by other management strategies like lean construction. The difference lies in how continuous improvement is achieved. According to lean principles, continuous improvement is acquired by a highly streamlined working process where change or variety should be avoided as a waste (Salem & Zimmer, 2005). However, agile management obtains continuous improvement by learning from lessons and changes throughout the entire project lifecycle, which is an iterative and incremental process (Hass, 2007).

An effective communication mechanism is critical in this process. One study indicated 70% of the delays in construction were due to lack of timely and adequate communication between the parties involved (Siddiqi & Akinhanmi, 2006). Encouraging a learning culture within organizations is considered as an alternative way to improve communication, especially on a dynamic construction jobsite, which contributes to quick decision-making and change implementation (Love et al., 2000). For the learning organization, Macher (1992) addressed that total quality management (TQM) featured by empowerment and partnership can provide an environment where continuous learning can thrive. TQM also fosters continuous improvement in a learning organization (Oakland & Sohal, 1996) which demonstrates organizational capacity for changes (Watkins & Marsick, 1993).

3.2.6 Information Technology Integration

Information technology has changed the way people manage and perform construction project activities but there is still room to fully integrate them into this management process. Faced with constantly changing technical and management requirements, construction professionals can turn to software tools to track and manage projects efficiently. Flexibility is another advantage when information is conveyed and reviewed via data infusion, internet and Building Information Modeling (BIM) in a real-time fashion.

More potential benefits are being recognized by increasing research efforts on it. A concept modeling framework has been presented centralizing project databases generated by all entities for workflow and electronic document management, and ultimately supporting a collaborative design process in construction (Van Leeuwen & Fridqvist, 2006). In order to deal with the uncertainty of construction, simulating "what-if" scenarios is more than necessary. Marx and König (2011) proposed discrete event simulation based on BIM that can be used to support construction scheduling, which consequently allows more responsiveness and "tangible" decision-making. Ideally, it is good to develop a virtual organization of construction (Jiang et al., 2011), a project-based dynamic organization that is supported by information technology integrating the advantages of all project entities to form core competencies.

3.2.7 Research Motivation

The studies above illustrate that the proposed five agile enablers are consistent with agile capabilities as presented in Chapter 2. However, literature results are still inadequate to justify the five enablers due to the limited scope of different research and theoretical inference. Also, literature findings are still less-organized and ambiguous to express the expectation of being agile and its potential practice.

Therefore, the motivation of this study arises mainly from how we can verify the proposed agile enablers and the whole idea of agile construction management. With an initial research goal of reducing construction delays, this study conducts both qualitative and quantitative research on agile ideas and enablers from a strategic perspective to analyze and compare their potential application in construction.

3.3 Methodology

3.3.1 Overview of Research Method

In order to explore the potential application of proposed agile enablers in construction, a two-step research method was employed. Qualitative interviews were conducted for a strategic and conceptual analysis of agile enablers applied in daily project management. Moreover, the agile ideas were further verified particularly in dealing with time-delays in construction through a quantitative case study. In general, the whole research process is illustrated in a flowchart as shown in Figure 3-1.

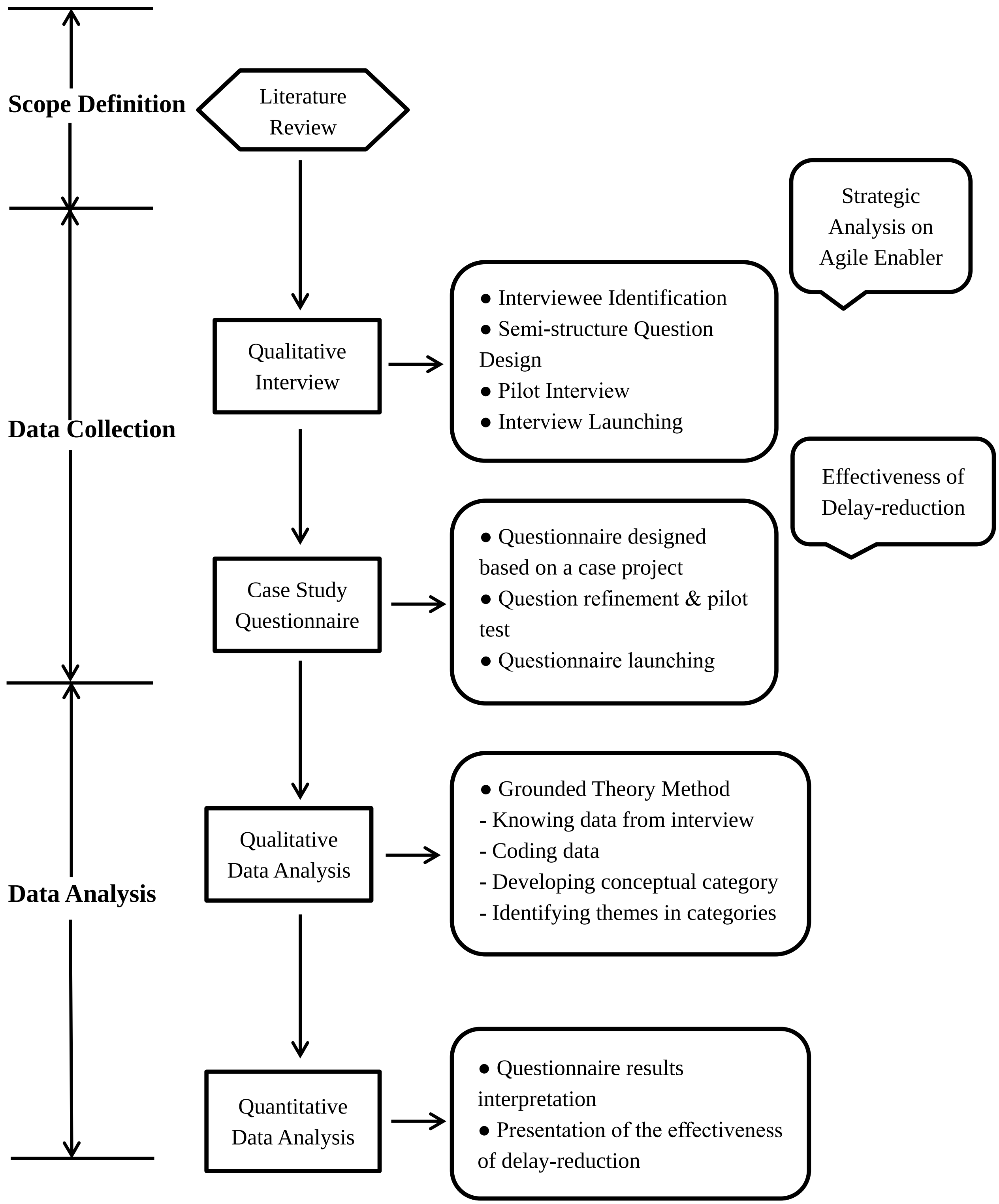

Figure 3-1. Flowchart of the research process

3.3.2 Qualitative Data Collection

Construction management literature requires the adoption of qualitative methods because of its nature of project-based and people-oriented activities with variables difficult to quantify (Swarup et al., 2010). In qualitative studies, data collection tools include interviews, surveys, observation and archival research (Myers & Avison 2002) which can be used in a combination to fulfill various objectives since no priority of methods was observed (Sandelowski, 2000). In this study, qualitative data were collected through interviews and supplemented by conducting a follow-up case study.

3.3.2.1 Qualitative Interviews

Agile construction management is still emerging in this industry. The primary purpose of this study is to conceptually provide information about this emerging idea. Accordingly, qualitative interviews were considered as an appropriated technique for this type of research in construction literature. Tennant and Fernie (2013) investigated the current practice of organizational learning in UK construction supply chains by conducting semi-structured interviews with clients, material suppliers and contractors. An extensive interview study led to a deeper understanding of sustainable building project delivery (Swarup et al., 2010). Interviews with safety leaders as a critical tool for data collection were utilized to analyze the safety culture in one of Australia's largest construction organizations (Biggs, et al., 2013).

A common attribute of these research studies is that interviews were effectively used for assessing attitudes, perceptions and values of innovative ideas in construction

(Silverman, 2006) with major benefits of improved response rates, convincing explanation of topics, flexible question setup and clarified answers (Oppenheim, 2005).

3.3.2.2 Interviewee Selection

As for the method to identify interviewees, a "snowballing technique" (Green et al., 2010) was used during initial interviews with informants who might provide additional interview participants to contact. In addition, the diversity of interview subjects was considered so as to reduce potential reactivity bias (Maxwell, 2005). Nine interviewees from different construction-related entities were identified and approached for interviews, including three owners, one architect, three project managers from general contractors, one executive director of a sub-contractor, and one university professor in the construction area.

3.3.2.3 Construction of Effective Interview Questions

The strategy of developing interview questions follows a semi-structured format where each enabler was introduced with a related example followed by pre-defined questions. The questions consist of consistent SWOT (Strength, Weakness, Opportunity and Threat) questions and open questions to access the respondents' in-depth perception toward agile construction management.

SWOT analysis, originated in the business management discipline (Weihrich, 1982) is a well-known approach for auditing the overall strategic position of a business and its environment (Tutor2u, 2010). The usage of SWOT analysis has been reported in many fields including the construction sector. For example, Shen et al. (2006) used the tool to analyze the situations for foreign-invested construction enterprises in China. The results of an improved SWOT analysis were related to some mathematical models assisting in identifying influential factors for strategic planning in the construction industry (Lu, 2010).

The SWOT investigation of agile construction management contributed to promoting agile ideas in three major ways. First of all, it allows stakeholders to gain a deeper understanding of agility and its enablers. Also, it helps identify application opportunities for handling delays as well as main concerns that are faced by the construction industry. Lastly, the results can be recorded as useful information to guide the development of agile construction in the future.

In this study, four structured questions in a SWOT order were designed for each agile enabler as shown below. In addition, some open-ended questions were prepared to ask about the respondents' overall impression of agile ideas as well as other possible approaches to agile construction management.

1) What are the advantages of this enabler for handling changes that cause delays?

2) What are the disadvantages of this enabler for handling changes that cause delays?

3) What types of delays might this enabler be best used for?

4) What things could inhibit the use of this enabler in construction?

3.3.2.4 Pilot Test and Formal Interview

Interview questions do not emerge fully-fledged (Oppenheim, 2005). There is a need to do pilot interviews that can assist the researcher in determining if there are flaws, limitations, or other weaknesses within the interview design and will allow researchers to make necessary revisions prior to the implementation of the formal interviews (Kvale, 2007). Accordingly, the author did pilot interviews with fellow graduate students in the Department of Civil Engineering. During this process, questions were tried out, recomposed and improved on in an accessible and logical manner.

As a result, the author completed nine interviews in total, including seven face to face interviews and two telephone interviews with an average duration of two hours. Depending on the responses, the interviewees were induced to expand ideas by follow-up or probing questions. All conversations were recoded with the explicit permission of the interviewees, and subsequently transcribed for later qualitative analysis.

3.3.2.5 Case Study Questionnaire

When it comes to a method commonly used to validate a conceptual theory and its application in construction research, Taylor et al. (2009) suggested that case studies allow researchers in the construction discipline to study phenomenon set in reality, therefore allowing them to witness tangible decision made on real issues of time, cost and quality.

With the goal of verifying the potential of agile enablers in reducing construction delays, a case project was identified and relevant information was converted to a questionnaire about how delays could be reduced if each agile enabler had been applied to a specific delay scenario. The prelaunch stage of the questionnaire referred to the procedure followed by previous research (Palaneeswaran & Kumaraswamy, 2003; Nourbakhsh, et al., 2012), including: questionnaire design, refinement, pilot testing and questionnaire launching. Results came out as qualitative data in linguistic terms which were later transferred into numerical values. The subsequent quantitative analysis focused on the comparison between agile enablers from different perspectives.

3.3.2.6 Case Project Description

The selected case study was a UNM project that renovated 9,937 square feet in Logan Hall for the clinical neurosciences core facility. The project consolidated and upgraded existing facilities, including several laboratories, data analysis spaces, collaborative working areas and building infrastructure. Based on the information provided by the UNM Office of Capital Projects (project owner), a conference room renovation was selected as the subject for this delay-reduction analysis.

The conference room job consisted of 14 activities which were subjected to two types of delays. One was the delay of the start date. For example, the project was planned to start on Sep. 29, 2012, while it actually started on Nov. 8, 2012. All activities suffered differently from the late start. The other delay type was a delay in working duration during the execution of activities. Accordingly, the job was planned with an original duration of 26 days and it was finally completed in 50 days, with 24 days of delays.

The delays resulted from the following reasons: 1) Changes by owners and designers to the original design; 2) Mismanagement of some activities as the general contractor pulled out the original superintendent to other jobs when work was only halfway done; and 3) Activities could not proceed due to lack of design information (late response to submittals).

3.3.2.7 Questionnaire Design

Based on the information provided by the case project, three delayed activities were picked out as samples associated with three different delay causes.

1) Owner-driven delay: the start of ceiling grid installation was postponed for 46 days due to owner's changes leading to redesign of the ceiling pattern.

2) Design-driven delay: the vinyl base was completed behind the original schedule by twelve days due to the lack of design information (late response to submittals).

3) Contractor-driven delay: the duration of door installation suffered a two-day delay because workers lacked clear instructions during the turn-over process of reassigning a superintendent.

The questionnaire included twelve structured questions, each embedded with a specific agile enabler. For example, the enabler of information technology integration was incorporated into a question as "The vinyl base was originally planned to be completed in one day. But due to the lack of design information (late response to submittals), the activity ended up lasting thirteen days. To what extent do you think the delay could be reduced if the designer and contractor, at the very beginning of a project can work on the same platform like BIM which can convey real-time updates of change information to all parties?" The complete version of the questionnaire was composed of four parts: introduction and ethic announcement, background information, case project description and questions (See Appendix A for the complete questionnaire).

3.3.2.8 Questionnaire Refinement and Pilot Test

In order to measure the magnitude of delay reduction by agile enablers, multiple choices were given to indicate the respondents' attitude for each question. Attitude statements were presented in a Likert-type scale, a psychometric scale commonly involved in designing questionnaires (Wuensch, 2005). When responding to a Likert questionnaire item, respondents specify their level of agreement or disagreement on a symmetric scale range that captures the intensity of their feelings for a given item (Burns A. & Burns R., 2008). The scale statements in this study were defined as a five-point Likert scale of "completely reduced, significantly reduced, somewhat reduced, slightly reduced and not reduced."

After the questions were arranged, a quality review was conducted by the author's advisor professor to check the clarity, coherence and relevance of the questionnaire. Additionally, a pilot test of the questionnaire was performed by the author's fellow graduate students. Then necessary revisions were made to ensure that the final version fulfilled the objectives of the study prior to formal launching.

3.3.2.9 Questionnaire Launching

The questionnaire was delivered as the follow-up part right after the SWOT interviews. The advantage of this arrangement is that the interview participants still have fresh memory of relevant information of agile enablers, and answer questions more comfortably after previous conversation. The survey ended up collecting nine questionnaire responses among which six copies were completed at the interviews and the remaining three copies were received shortly after the interview by email.

3.3.3 Qualitative Data Analysis

Qualitative analysis transforms narrative data into findings by an interpretative process (Patton, 2002). Some approaches such as grounded theory, content analysis and phenomenology are commonly used methods to attain that transformation. Grounded theory, a systematic methodology in the social sciences involving the discovery of theory through data analysis (Martin & Turner, 1986) was selected as the qualitative analysis method in this study.

The grounded theory approach enables the researcher to systematically tie the empirical findings to the emerging conceptualization (Corbin & Strauss, 2008) via an iterative process between the data and relevant theory bases. Using the grounded theory approach, the major analysis process involves: knowing data, coding data, developing conceptual code categories and identifying themes and connections within categories (Creswell, 2007; Lehtiranta, 2011).

3.3.3.1 Knowing Qualitative Data

Qualitative data of agile ideas and enablers comes from the summary of individual interviews and written comments on questionnaires. By using memoing, a common qualitative technique in which textual data are transformed into conceptual data captured within the researcher's thinking process (Locke, 2001), the author firstly transcribed all interviews to a written summary and then read the summary repeatedly to obtain a sense of the whole. For unclear points or follow-up questions, follow-up emails or phone calls were made to further refine the interview data to obtain deeper understanding of the interview results.

3.3.3.2 Coding Qualitative Data

Qualitative research is to provide a subjective interpretation of narrative data through the systematic classification process of coding and identifying themes (Heieh & Shannon, 2005). During this process, coding as a key step is defined as marking the segments of data with symbols, descriptive words, or category names (Silverman, 2006). Depending on the way of coding, grouped data may be enumerated, which commonly is used for investigating the key themes of interview findings (Howe, 1990). When reading the interview transcript, the author conducted initial coding by labeling meaningful data segments according to their main relevant themes (See Appendix B for the qualitative data coding sheet). The frequency of their appearance was counted as an indicator of the strength of the presence of the term or phrase. Interrelated sections of initial codes were then clustered into more meaningful concepts, thereby producing several main codes.

3.3.3.3 Developing Conceptual Categories

After the initial data coding was completed, the following step attempted to summarize and organize codes into different categories. Since the interview questions primarily focused on the SWOT performance of each agile enabler, the major categories of codes were formed in several meaningful themes. The advantage of grouping these analytical categories lies in knowledge from the literature was compared to learning from the interviews and, thereby, led to more specific theoretical explanations (Strauss & Corbin, 1998).

3.3.3.4 Themes and Connections within Categories

In order to gain in-depth insight into theoretical properties and actual experience of agile ideas and relevant approaches, the last step of this analytical process was to identify and analyze potential interrelations between coding categories. Ultimately, overall outcomes of key themes and logical relationship between them may generate a grounded theory for agile management, which is an inspiring theory whose basis is in the reality of construction.

3.3.4 Quantitative Data Collection

3.3.4.1 Questionnaire Interpretation

If qualitative analysis of agile enablers attempts to illustrate a “big picture” of agility integration in construction, quantitative analysis is to verify the effectiveness of agile enablers particularly in reducing time delays. A case study was performed in terms of a questionnaire survey. Quantitative data was extracted from chosen answers in word description in the questionnaire, which were converted from Likert scale options to numerical values.

Interpreting subjective data into percentiles had been recommended as a reliable assessment method since using percentiles to quantify assessors' beliefs can help obtain less-biased outcomes (Apostolakis & Mosleh, 1982). Especially, some research in experimental psychology indicated that subjective estimates for certain percentiles of a population can be reasonably accurate, especially for the 25th, 50th, or 75th percentiles, also known as the lower, median, and upper quartiles (Alpert & Raiffa, 1969; Lichtenstein et al., 1977). Accordingly, the scale statements of "completely reduced, significantly reduced, somewhat reduced, slightly reduced and not reduced" in the case study questionnaire numerically implies in the same order as "100%, 75%, 50%, 25% and 0%" reduction of original delay.

3.3.4.2 Questionnaire Result

The results from the case study questionnaire are presented in Table 3-1.

According to Table 3-1, twelve questions were asked on applying the agile enablers to three activities from the case project in each questionnaire. All nine interviews are divided into two general types: owner (including an architect respondent) and contractor (general contractor and sub-contractor) groups, presented as O1 to O5 and C1 to C4 for short.

Activity A, B and C stand for selected activities, subject to owner-driven, contractor-driven and designer-driven delays respectively. E1 to E5 refer to five agile five enablers of 1, Real time resource monitoring with field feedback and productivity measurement; 2, Self-autonomous work teams with multi-functional crews; 3, Short-term planning along with concurrent execution of activities; 4, Continuous improvement based on learning organization; 5, Information technology integration. As mentioned above, all linguistic descriptions of delay reduction in terms of one activity versus one enabler are interpreted as corresponding percentage values. The effectiveness of delay reduction is summarized by averaging these percentage values in terms of activity-based, enabler-based and interviewee group-based results.

Table 3-1. Result for case study questionnaire

Activity-Enabler	Owner					Contractor				Activity-based Average	Enabler-based Average	Group-based Avarage	
	O1	O2	O3	O4	O5	C1	C2	C3	C4			Owner	Contractor
A-E2	25%	75%	0%	50%	75%	50%	75%	75%	25%	0.57			
A-E3	50%	25%	50%	75%	75%	75%	75%	50%	25%				
A-E4	75%	100%	75%	75%	75%	75%	75%	75%	75%	Owner-driven dealy			
A-E5	50%	75%	0%	0%	75%	0%	50%	75%	75%				
B-E1	25%	75%	100%	75%	50%	0%	25%	50%	25%	0.62	E1: 0.47	0.65	0.25
B-E2	75%	100%	100%	75%	75%	50%	0%	75%	50%		E2: 0.61	0.63	0.58
B-E3	50%	100%	100%	75%	75%	100%	50%	75%	75%	Contractor-driven delay	E3: 0.67	0.68	0.66
B-E4	50%	75%	75%	50%	75%	100%	50%	75%	75%		E4: 0.70	0.68	0.73
B-E5	50%	50%	50%	50%	75%	50%	25%	50%	50%		E5: 0.48	0.48	0.48
C-E2	50%	25%	75%	75%	75%	75%	75%	75%	75%	0.6			
C-E4	50%	75%	50%	50%	75%	75%	75%	50%	75%	Designer-driven delay		0.62	0.58
C-E5	25%	50%	0%	75%	100%	50%	50%	25%	75%				

3.3.5 Quantitative Data Analysis

Information from Table 3-1 indicates that delay reduction can be anticipated based on the assumption that proposed agile enablers were applied to the selected case project activities. The effectiveness can be assessed in different ways. Considering the five enablers as an integrated agile strategy, the author did an activity-based comparison of the schedule before and after the agile strategy was used. An “agile schedule” for the selected three activities was obtained by calculating the mean of the anticipated delay reduction provided by all used enablers. Moreover, the five enablers were also compared with each other in terms of each one’s contribution to delay reduction for selected activities. Another analysis is to evaluate the results sorted by interviewee group types. Since the number of interview samples is limited, the average delay reduction by each enabler was compared across selected activities only between owner and contractor groups.

During the analysis process, the main concern regarding the effectiveness of delay reduction for each enabler is its subjective nature that accumulated along the all respondents. Variability produced by each respondent may affect final judgment on the performance of individual agile enablers. In this case, inter-rater agreement (IRA) analysis which refers to the absolute consensus in ratings furnished by multiple judges for one or more targets (Bliese, 2000; LeBreton et al., 2003) was performed to investigate the agreement level of interview respondents for each enabler to reduce delays that occurred in the case project.

Estimates of IRA are used to address whether scores furnished by judges are interchangeable or equivalent in terms of their absolute value. For the specific analysis method, results are usually reflected in the form of an index via some estimate of within-group rating dispersion (LeBreton & Senter, 2008). There are several methods available for testing inter-rater agreement. The method of average deviation (AD) index, one of simple and robust method as addressed by Burke et al. (1999) was used.

The AD index can be estimated around the median (AD_{Md}) for a group of opinions rating a single target (enabler delay reduction) on a single item (one enabler). AD_{Md} values can be computed as follows:

$$AD_{Md(j)} = \frac{\sum_{k=1}^{K} \left| X_{jk} - Md_j \right|}{K}$$

Where k=1 to K opinions, X_{jk} is the kth evaluator's rating on the jth item, and Md_j is the item median taken over all evaluators. As suggested by Burke and Dunlap (2002), the AD_{Md} index represents the disagreement level among the evaluators, i.e. how far is a single opinion floating away from the median. Here smaller average deviation means a higher level of consensus among the evaluator and vice versa.

Burke and Dunlap (2002) addressed a cut-off value of c/6 which can be used to determine whether there is a consensus among evaluators, where c represents the number of response options. Values lower than the cut-off point mean acceptable levels of consensus, while a value that falls over the cut-off point would indicate a problem of consensus between evaluators.

3.4 Results

3.4.1 Findings of Qualitative Interview

According to principles of the grounded theory approach, the validity and value of qualitative research is grounded not in objective observations, but in context-dependent interpretation of "what practitioners say about practice" (Lousberg & Wamelink, 2009). The summary of interviews indicate each respondent put in-depth thought into "what if" each agile enabler was applied to construction. Meanwhile, SWOT-formatted questions triggered more strategic and logical thinking on each agile enabler's potential in handling delays on ever-changing construction jobsites. Many insightful and constructive opinions were generated in six themes:

Theme 1: Issue of Initial Investment

When it comes to upfront investment for the agile enablers to be implemented in construction, the most "costly" enablers, as suggested by all respondents are Enabler 1 (resource and productivity monitoring) and Enabler 5 (information technology integration). Contractors felt it is time-consuming to do more paper work for productivity data collection and analysis. Initial start-up expense in terms of time and money can be a burden for small construction companies to provide software tools and hire professional employees to do mobile site control or 3-D models.

Apart from the time and money issue, some contractors also mentioned they are not willing to pay for the extra-work of doing productivity data analysis. Because if their superintendents were assigned this task, there was a fear of wasting their skills in regular on-site controls when they have to spend time on something like computer-based data analysis they are not good at. Training is another issue related to investment. Both owners and contractors agreed that training existing people relevant technologies is a considerable portion of initial cost, let alone training them to understand and perform learning-based improvement. What is more, another investment lies in risk sharing for all entities involved. Overall, in the context of a slow construction market, most respondents were not very open to upfront investment on agile enablers unless they obtain proof of benefits brought by agile practice.

Theme 2: Issue of Learning Curve

Learning curve is another issue in pursuing agility in construction. Even if being agile sounds like a good idea, various constraints on fulfilling new ideas still exist as anticipated by most respondents and is presented across enablers in different aspect_as shown in Table 3-2:

Table 3-2. Learning curve issue for agile enablers

Learning Curve Issue	Resource & Productivity Monitoring	Self-autonomous & Multi-functional Team	Short-term Plan & Concurrent Activities	Continuous Improvement from Learning	Info Technology Integration
Resistance to Change	√	√	√	√	√
Internal Constraint	√	√	√	√	√
External Constraint		√		√	

Resistance to Change

One universal concern addressed by respondents is that people might be resistant to trying agile enablers for several reasons. According to contractors' opinions, experienced superintendents tend to resist letting data analysis on productivity trending to replace their empirical practical knowledge. A similar issue was mentioned by a subcontractor that too much collaborative learning (enabler 4) could make some people feel less-valuable in the face of higher skilled people; they can even be in fear of losing jobs due to a narrow-minded perception on it.

Most respondents expressed their concern about rigid adherence to the routine of existing working process and it is challenging to develop a culture of accepting changes. As for related reasons, one owner pointed out: "*People resist trying new things out of their comfort zone when they don't truly believe or understand the value of this approach*". Another critical reason lies in the related proof of benefit that is still elusive. For example, some contractors thought the advantages brought by some agile enablers like BIM integration are limited since the owner is the primary one who could benefit from 3-D modeling. BIM for contractors only provides extra value but is not essential to basic requirements in most cases. Limited understanding of return on investment (ROI) was also described from the perception that benefits are better generated in the short-term rather than the long-term.

Internal Constraints

During the interviews, the application of all five agile enablers was related to major constraints: limited resources, working conditions and complicated coordination.

Resources mentioned here refer to extensive requirements on implementing different agile enablers. Most respondents repeatedly addressed the lack of uniform trained personnel, technologies, financial capabilities and standard practice as primary obstacles which could hinder the use of each agile approach, which is in line with concern over initial investment. Additionally, on-site conditions in construction can be another influential factor. As one sub-contractor pointed out, overlapping activities could be limited due to limited working spaces in case of trade congestion and stacking.

Since many agile approaches need collaborative efforts from all project entities, coordination is considered as a big obstacle in the way of agile practice. On the one hand, one challenge results from the way of procuring a construction project, which means that general contractors find difficulties in keeping sub-contractors on the same page of using agile approach. For example, one contractor stated it is challenging to have a team effort from all subs for the enabler of continuous improvement which requires a corporate culture of positive thinking on accommodating and embracing changes.

Information technology integration could lead to other coordination problems when project members are not working on a same software platform. Although using the same software application like BIM, coordination problem still occur as the benefit of software is still dependent upon the people who operate it. As one sub-contractor described, BIM should consist of two parts: information modeling and information management. If you cannot manage data properly, models are useless. Interference is generated when engineering modelers put wrong parameters for his or her designed items. But the reality as usual is no one wants to change their own model to accommodate the error, which could result in various problems.

External Constraint

Agile enablers could be inhibited by some external factors in terms of rules or regulations. Mentioned most in the interviews is “union’s control.” Both owner and contractor expressed it is hard to implement self-autonomous and cross-functional working crews (enabler 2) in the union environment where the culture is based on hierarchy. Similarly, highly cooperative learning organization is challenging to achieve as unions discourage making decisions collaboratively.

The idea of multi-functional crews is subject to obstacles from government regulation on the construction industry. A common concern brought by contractors was the pay level issue. Some thought it is hard to evaluate skill-level and determine pay-levels for multi-functional crews. Others pointed out that the rule of state wage rates requires workers to be paid according to what types of trades they belong to. What is more, it is hard to have multi-functional crews for public projects which require laborers being separated into trades.

Theme 3: Potential Benefit

In spite of initial investment and learning curve issues, all interview respondents acknowledged the potential for the idea of agility and believed the proposed agile enablers could benefit the whole construction industry. In order to accomplish overall agile project performance, it requires combined contributions from all agile enablers. Accordingly, Table 3-3 presents all possible advantages across the five enablers.

Table 3-3. Potential benefits for agile enablers

Potential Benefit	Resource & Productivity Monitoring	Self-autonomous & Multi-functional Team	Short-term Plan & Concurrent Activities	Continuous Improvement from Learning	Info Technology Integration
Better Response to Changes	√	√	√	√	√
Improved Project Performance	√	√	√	√	√
Enhanced Collaboration		√	√	√	√
Continuous Improvement	√	√		√	

Better Response to Changes

One core value of agile construction management is to allow the project to thrive under continuous and unpredictable changes. Interview feedback indicates the agile enablers can help handle changes in a three-step process: stay responsive, keep proactive, and adapt to changes.

For self-autonomous teams (enabler 2) along with short-interval planning (enabler 3), most contractors addressed that pushing decision making to the lowest level of an organization possible makes for a quicker and more responsive approach to changes. Using mobile project software (enabler 5) helps project management to distribute information and make real-time decisions to address working assignments.

Productivity tracking (enabler 1) helps a project to stay proactive by moving controls forward. The productivity data obtained could be used in short-interval review of plans (enabler 3) so as to make resource data feedback more intelligent in a fluid jobsite and helps track activities individually. Iterative processes like this in the long term allow projects to become "immune" to changes by learning from lessons continuously.

Improved Project Performance

Another major benefit brought by agile enablers is to improve overall project performance. Contractors valued agile ideas for their huge potential of time and cost saving in the long term even though it needs preloading temporarily. For example, a project manager from a general contractor stated using mobile software to track RFIs (Requests For Information) with real-time data can greatly speed up this process. Short-term planning which helps uncover potential problems implies potential time and cost saving, which is a reward for a learning organization in the long run.

Higher working efficiency is largely anticipated by all respondents. Real time productivity data collection and analysis could help contractors clearly know themselves about how to work in a more productive way from previous experience. When they know productivity trending, they could work on how to narrow the band of productivity variance and ultimately change and improve the trend. Multi-functional crews and overlapped activity schedules were also believed to contribute to higher individual and project productivity. In addition, workmanship could be improved since multi-functional crews can provide expedient efforts based on educations in different trades, which brings higher quality based on learning from previous jobs.

Enhanced Collaboration

A competitive market has driven collaboration to become a key factor for the success of a construction project, which is a specialized attribute of agile management principles. Similar comments were made during interviews in terms of different enablers. A learning organization implies team benefits from sharing information and rewards especially in the pre-construction phase. As a contractor stated, "*owners and designers who are most likely to make changes can sit together and learn from previous changes*".

Self-autonomous teams could facilitate developing a more collaborative atmosphere and help build awareness of communication. During short-interval planning, collaboration is further improved among team members. What is more, to build better customer relationships, agile management could become a good marketing method for contractors to show owners their special advantages.

Continuous Improvement

For any project entity, continuous improvement is more than an attractive "promise" a management can make. It grows in agile management from iterative cycles of learning and development, which avoids repeating the same mistakes. A contractor's project manager described: "*A lot of continuous improvement with us is from input coming back from the field on better ways to perform the same task*". It works better for large projects where you can learn and improve through a repetitive process.

From a manpower standpoint, encouraging multi-skill trained crews can increase job site satisfaction in terms of higher productivity and motivation. Another point for continuous improvement lies in the refining of a contractors' project database. Both productivity tracking and BIM-related technologies were considered appropriate approaches to this task.

Theme 4: Development of an Agile Culture

Some respondents realized that another potential benefit for promoting agile enablers lies in supporting a culture of being agile in the long run. For example, monitoring resource investment helps with knowing why productivity variance occurred and supports the mentality of being proactive. Developing a culture of learning from changes through a partnering session with all key stakeholders can instill this agile idea upfront before design.

"*Construction has too many constant flows so the agile idea sounds exciting to be a new management philosophy in construction*", as suggested by a contractor. When it comes to who should take the lead to promote agile ideas, contractors expressed owner and government-type agencies will be the ones who have the capability to do it because of the higher level power limit. Subsequently, there comes a demand on developing related standard codes of agile construction management. According to owners, agile mentality means a real team spirit which gets all parties involved and collaborates with each other before construction starts. For contractors, they cared more about staying agile to be competitive in this competitive market.

Other approaches to an agile mentality were also discussed in the interviews. Major opinions are summarized below:

- Develop construction documentation that can involve all project participants in the design process and ultimately form an overall agile plan rather than some sporadic requirements.

- Build an agile supply chain as material suppliers should be involved and coordinate with other entities.

- Multi-functional capability should be expanded to management-level teams because only if people who make decisions have the agile ideas, can they really support more systematic agile approaches.

- Develop an agile project delivery system in terms of unified methods which break down the barrier between designers and contractors by promoting real partnership not only on a project basis but on a whole industry basis.

Theme 5: Limitation and Skepticism on Agility

Beyond the great potential of agile construction as mentioned above, some thoughts on limitations of some enabler application were also obtained from the interviews. According to some contractors, the idea of multi-functional crews could work better for a team composed of people from different trades rather than a person with a multi-skill set. They felt it is usually hard for a multi-functional person to keep equal expertise in all skills individually. If a person who is a jack of all trades but no expertise for any one of the skills was assigned multiple tasks, it could be risky for productivity and workmanship.

The issue of project types where some agile enablers are better used for was raised. For small residential projects, it was more suited to assigning multi-functional crews to handle multiple tasks flexibly. Large-scale commercial or industrial projects prefer having workers with high expertise in one trade to be more productive, explained one contractor. Another example is about information technology integration. Incorporating BIM is considered not very cost-effective on small projects.

Another limitation brought up was the concern about slow decision-making. In a self-autonomous team, individuals at the lower levels of an organization may not have all the information necessary for the best decision. Consequently, decision-making processes could be slowed down if information and knowledge are not shared and managed properly as no one is really leading. Additionally, short-interval planning might not "anticipate" long-term plans or meet long-term requirements due to a lack of thinking in the "big picture" of project objectives. Some respondents even expressed a skeptical attitude toward some new and unproved agile ideas, including:

- Continuous learning processes could cause fatigue from constantly looking to improve; there may be operations that are already honed and not in need of improvement.

- People could ignore the importance of personal checks on site if they over-rely on 3D modeling

- Too much information can slow down the construction process.

Theme 6: Matching Enablers to Delay Causes

One purpose of the interview was to find out what types of delay causes each agile enabler could be better used for. The results are fairly consistent and indicate most respondents agreed that all agile enablers can work for all types of delay causes to a different extent. For enablers which are designed in particular to be performed by contractors, like productivity tracking, multi-functional crews and short-interval planning, they can mitigate contractor-driven delays.

When asked about the priority of delay reduction, the contractors emphasized uniformly that owner-driven delays are the primary source of delay that could be effectively reduced by four out of the five proposed enablers except for resource and productivity monitoring. Other common delay types mentioned were resource-related (materials and equipment issues) and field condition-related (weather and other site condition issues) delays. The results consistently showed they could benefit from three out of the five enablers respectively.

3.4.2 Findings of Case Study Questionnaire

The SWOT survey was conducted among nine construction professionals experienced in project management. Those surveyed included owners and contractors, representing different angles on certain construction situations. The 12 questions designed for the subsequent case study questionnaire regarded how three types of delay factors and five agile enablers could potentially work to reduce delays. As mentioned above, the scale statements were interpreted into quantitative percentages for the convenience of analysis. The results of the case study are presented below.

3.4.2.1 Activity-Based Result

Most surveyed believe the five enablers can reduce the delay to some extent, on an average of 60% as a whole. Among the three delay factors, owner-driven delays, design-driven delays and contractor-driven delays, the effectiveness of the five enablers shows no significant difference and the delay is estimated to be reduced by 57%, 60% and 62% respectively. Accordingly, an “agile schedule” after the enablers are applied is shown in Figure 3-2.

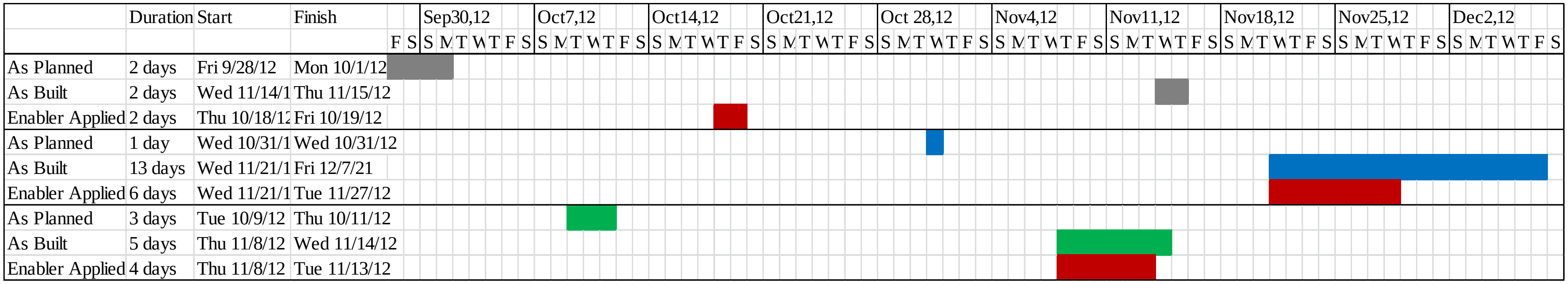

Figure 3-2. “Agile” schedule for selected activities

Activity A is categorized as an owner-driven delay. It was delayed by 33 working days in starting date, and was completed as planned in two days. After the enablers are applied, the delay is expected to be shortened to 14 days.

Activity B is categorized as contractor-driven delay. It was delayed by 2 days in duration due to an inefficient turn-over process of the on-site superintendent. After the enablers are applied, the task is expected to be completed in 4 days, only one more day than as planned.

Activity C is categorized as design-driven delay. It was delayed an extra 12 days waiting for the response from the designer. After the enablers are applied, the task is expected to take half the time as it actually took.

From the above analysis, it is clear that the five enablers are believed by construction professionals to be effective in reducing all three types of delays. This also confirms the rationality of the five enablers, which cover a relatively complete construction process with consideration of as many delay causes as possible. For example, Enabler 1 treats delays by correcting poor on-site recording by superintendent, which is very detailed, as is mentioned in the interview by many to help stay proactive, save time and build database. Enabler 2 requires workers to be self-motivated, which leads to higher efficiency for both individual workers and management and higher job satisfaction level. Enabler 3 tries to save delays from upper management level using upfront short-interval planning, bringing potential savings in cost and time by responding to changes promptly. Enabler 4 focuses on building a learning-from-the-past mechanism within the whole organization, the "best immunity to potential changes" as described by one interviewee. Enabler 5 helps reduce delays from technical perspective promoting information sharing among parties, allowing real-time decision making and problem recognition. Combining all five enablers, the agile concept is interpreted into useful applications to treat delays from the root.

3.4.2.2 Enabler-Based Result

After categorizing data into five individual enablers, we find the contribution of each enabler varies in reducing delays, as is shown in Figure 3-3.

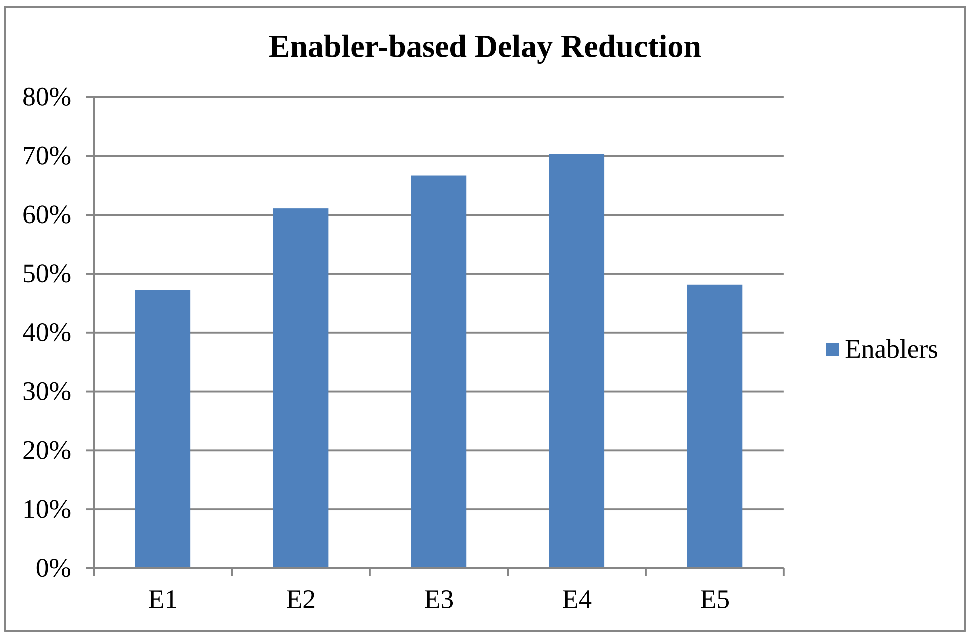

Figure 3-3. Result for enabler-based delay reduction

Among the five enablers, Enabler 4 (continuous improvement based on learning organization) is believed to cut delays by 70.37%, the highest effectiveness, while Enabler 1 (real time resource monitoring and productivity measurement) is considered the most pessimistic in reducing delays at 47.22%. Enabler 5 (information technology integration) is only a slightly more effective at 48.15% delay reduction than the lowest.

The other two enablers are in the middle at 61.11% for Enabler 2 (self-autonomous work teams with multi-functional crews) and 66.67% for Enabler 3 (short-term planning along with concurrent execution of activities).

The result seems interesting and goes beyond the author's expectation. Before conducting the survey, a stereotype impression held about the enablers was that focusing on the activity itself as planned with concrete methods to guarantee the original plan, like those designed in resource and productivity monitoring, can better solve delay problems. But the result shows totally the opposite. Furthermore, information technology, such as BIM that has been widely used in construction to allow all parties to share real-time updates through the whole process, does not gain advantages over the rest of the enablers as was expected. The function of such systems either needs more adaptive function or recognition in the industry.

The results from a certain point enhance the basis of an agile construction management system that changes in construction are unavoidable, so embracing changes and adapting to changes is necessary. Compared with sticking to the original plan rigidly, multi-functional teams and flexible short-term plans obviously work better in unexpected situations. A learning organization that is able to learn from past experience is more likely to develop back-up plans for promptly responding to changes.

Apart from the general data above, it is also important to look into the agreement level upon which those surveyed give their confidence on each enabler. As is shown in Table 3-4, the professionals expressed different levels of confidence towards different enablers. Enabler 4 is believed by all professionals to reduce delays by 50% or more. On the same level of 50% and up, only half believe Enabler 1 will work. For both Enabler 1 and 5, there are answers to the two extremes, which means that some people think the delays can be completely reduced by using certain enabler while others evaluate the same enabler as useless. The disparity may come from different subjective judgments by owners and contractors, as well as their experience on past projects.

Table 3-4. Confidence level for enablers

Enabler	**100%**	**75%**	**50%**	**25%**	**0**
1	1	2	2	3	1
	11.11%	22.22%	22.22%	33.33%	11.11%
Accumulated	11.11%	33.33%	55.56%	88.89%	100.00%
2	2	15	5	3	2
	7.41%	55.56%	18.52%	11.11%	7.41%
Accumulated	7.41%	62.96%	81.48%	92.59%	100.00%
3	3	8	5	2	0
	16.67%	44.44%	27.78%	11.11%	0.00%
Accumulated	16.67%	61.11%	88.89%	100.00%	100.00%
4	2	18	7	0	0
	7.41%	66.67%	25.93%	0.00%	0.00%
Accumulated	7.41%	74.07%	100.00%	100.00%	100.00%
5	1	7	12	3	4
	3.70%	25.93%	44.44%	11.11%	14.81%
Accumulated	3.70%	29.63%	74.07%	85.19%	100.00%

As mentioned above, accumulated figures in Table 3-4 indicate Enabler 4 has achieved the highest agreement level because all of the figures regarding Enabler 4 are above the 50% level. In order to further check the inter-rater agreement level, the average of deviation (AD) can be used as a supplement to confirm the result in Table 3-4.

This measurement was introduced under the assumption that there is a relatively objective value for each item to be evaluated. In this particular project, the effectiveness of each enabler should come from experience in practice, in spite of evaluators' subjective opinions. The procedure and result of calculating the index is presented in Table 3-5.

Table 3-5. Result for inter-rater agreement calculation

Estimate of the Median					
Data No.	**E1**	**E2**	**E3**	**E4**	**E5**
1	0.25	0.25	0.5	0.75	0.5
2	0.75	0.75	0.25	1	0.75
3	0	0.5	0.75	0.75	0
4	1	0	0.5	0.75	0
5	0.25	0.75	0.75	0.75	0.5
6	0.5	0.75	0.5	0.75	0.75
7	0.75	0.5	0.75	0.75	0
8	0.5	0.75	0.75	0.75	0.75
9	0.25	0.25	0.25	0.75	0.75
10		0.75	0.5	0.5	0.5
11		1	1	0.75	0.5
12		0.5	1	1	0.5
13		1	1	0.75	0.5
14		0	0.5	0.5	0.25
15		0.75	0.75	0.75	0.5
16		0.75	0.75	0.5	0.5
17		0.75	0.75	0.75	0.75
18		0.5	0.75	0.75	0.5
19		0.5		0.5	0.25
20		0.25		0.75	0.5
21		0.75		0.75	0.5
22		0.75		0.5	0
23		0.75		0.75	0.5
24		0.75		0.5	0.25
25		0.75		0.5	0.75
26		0.75		0.75	1
27		0.75		0.75	0.75
#Alternatives	5	5	5	5	5
#Data (K)	9	27	18	27	27
Median (Mdj)	0.5	0.75	0.75	0.75	0.5
Single-Item ADMd	0.25	0.18	0.17	0.08	0.19

After grouping all the data into the table, the data are distributed among the five enables. Number of alternatives means the five scale options given for each question in the questionnaire. Number of data means how many ratings have been collected for each enabler. Based on the above formula, the median and AD index for each enabler can be calculated accordingly.

Once all the estimations have been performed, the results can be tested against the cut-off value, which represents the upper limit of disagreement. For the AD_{Md} index, the maximum degree of disagreement is derived from the expression: Number of rating alternatives/ 6, and in this case, equals 5/6 = 0.83.

At this point, it is easy to decide whether the result for a particular enabler is acceptable within the program, or not. It is clear in the table that every individual AD_{Md} index is under the upper limit permitted, indicating all the enablers show acceptable agreement. Enabler 4 has the most concentration among the evaluators while Enabler 1 is the least agreed on. This backs up the result in the first part.

Based on the above analysis, there is obvious disparity in ratings for certain enablers, so it would be meaningful to continue with a group-based analysis.

3.4.2.3 Group-Based Result

The group-based result is collected and illustrated in Figure 3-4 below. The professionals are divided into two groups: owners and contractors. Generally speaking, the two groups do not show much gap when evaluating the effectiveness of the enablers, indicating delay reduction by 61.67% and 57.81% respectively. Taking individual enablers, there is no obvious disagreement either except for Enabler 1, where there is a large disparity on reduction level between owners and contractors. Owners believe

Enabler 1 can reduce delays up to 65% while contractors are not that positive, giving only a 25% reduction level. Among the other four enablers, only Enabler 5 falls below 50% in delay reduction, leaving Enabler 2, 3 and 4 staying above the general level.

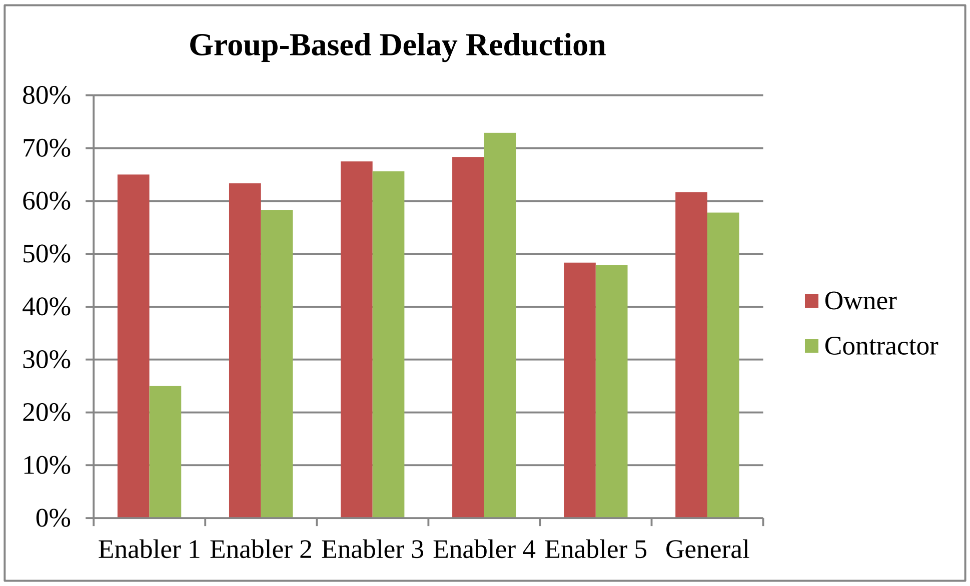

Figure 3-4. Result for group-based delay reduction

It is not difficult to speculate why there is such difference between the two groups in evaluating Enabler 1. In construction, owners positively think keeping records of material and productivity can effectively reduce delays, especially when they do not directly manage construction activities and assume one essential delay cause comes from poor management of their contractors. However, contractors think simply monitoring the activity is less useful when an unexpected delay occurs. In practice, unpredictable delays usually cannot be saved by following the original plan along with after-fact methods. Instead, infusing flexibility into the process and working on concurrent options prove to be more practical.

This group-based result again lends strong support to the agility concept in construction management. If a process is regarded as a system, the links and interactions undoubtedly provide its system designer with adequate room adding lubricant to the most fragile joints, preparing sufficiently for the sudden strike. In construction projects, following a well-planned order just limits such flexibility in handling delays.

3.5 Discussion

The results from both the interviews and the case study support the proposed agile construction management system in two ways:

First, the concept of an agile construction system is potentially achievable in construction management. For all the respondents, unexpected events in construction processes are possible to be handled in a flexible way of embracing changes rather than rigidly following the schedule, which is the spirit of agile construction. Although the idea was borrowed from early agile manufacturing practice, it is compatible with the construction industry.

Second, the five enablers do exist in construction practice. The respondents confirmed that agile enablers are not merely a “surprise pop-up” from early research, but effective methods that can enhance project activities and optimize the construction process. This is made vivid from numerous benefits and problems regarding using the enablers to reduce delays, as stated by respondents. Almost all five enablers are being applied to real construction projects to some extent.

Despite the above view, one vague part of the theory lies in the uncertainty of turning the enablers into consistent and low-cost mechanisms instead of costly separate methods. According to the respondents, one obstacle making agile construction less advantageous is the initial investment on both labor and money. Therefore, even knowing the room for potential benefits, construction entities are reluctant to step forward too much. As is shown in Figure 3-5, adoption of agile enablers in construction could be very similar to the classic "product life cycle" theory, with stages of emerging, climbing, maturing and declining. The only difference seems to be a "chasm" of learning curve between initial investment and future benefit. Analyzing the attitude of respondents, agile construction is still staggering in the first stage, waiting to be pulled up by forces strong enough to overcome the fear of investment. The faster we are able to fill in this void, the sooner we will see steady gain by using an agile construction management system.

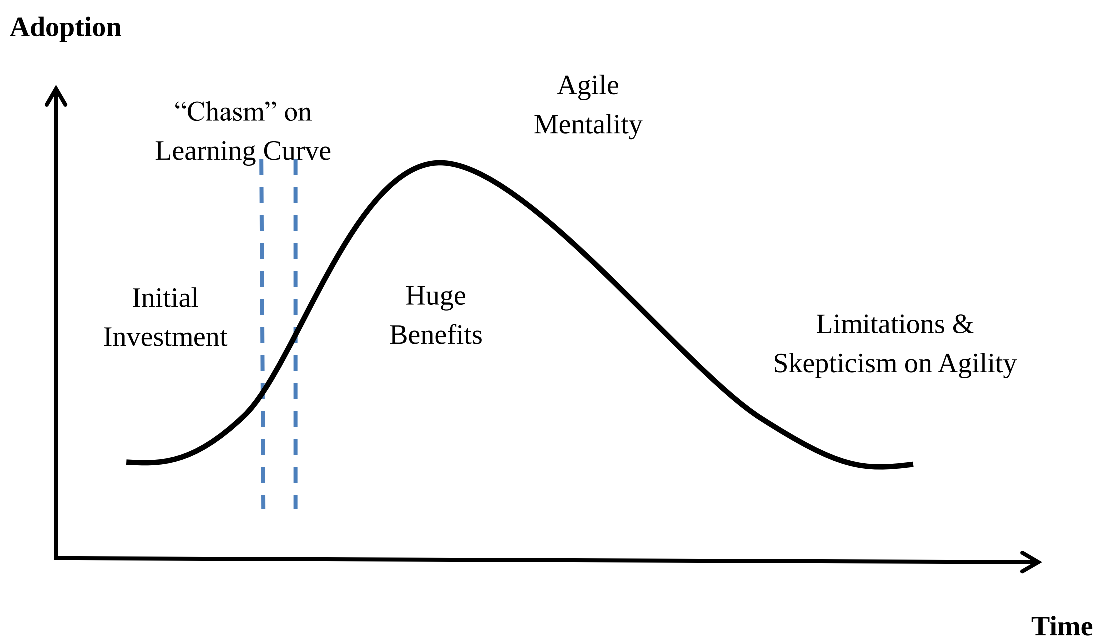

Figure 3-5. Process curve for agile enabler adoption

Another aspect one must look into when applying the enablers is how to evaluate the enablers ahead as some work better than others on certain delay types. The five enablers are extracted from manufacturing and construction practice, but not considered by respondents as equally applicable and effective. It is obvious that some cannot work with certain delays, such as Enabler 1, and there are still sharp differences in attitude towards certain enablers between groups. Taking the inapplicable enablers goes against time saving, and how to know if an enabler will work depends on the experience of construction professionals. This survey contains only nine respondents, making the pool of sample data too small. The author believes by expending the source of information, it would be possible to set up a set of evaluation systems by using experience variables, each enabler targeting matched delay situations, promoting an agile system as an easy and orientated application.

CHAPTER 4. CONCLUSIONS

4.1 Summary Conclusion

The concept of agile construction is inspired by agile manufacturing due to their similarities in activity process. In this thesis, the contribution of raising and validating the agile construction management system can be understood in four layers.

First, the system is triggered by delay control, which is common in construction practice. From a traditional perspective, different types of delays deserve specific methods of delay reduction accordingly. But these methods were not integrated from a higher systematic angle and can only be applied on a case-by-case basis. The agile construction management system sets off combining all delay causes and prompts the awareness of agility being instilled into the whole project delivery process from plan, procurement, design, and execution. This goes far beyond single problem-solving approaches.

Second, the system turns away from following the rigidly set plans and tries to work with delays by embracing changes in both proactive and reactive ways. When flexibility is planted into cooperation between all parties, on-site management, labor training and schedule adjustment, a construction project becomes more immune to swaying from the original plan with more elasticity. This balances the conflict between pre-set schedule and half-way adjustment.

Third, the framework proposed under an agile construction management system illustratively explains how several agility components interact with each other. It extracts from construction practice the core problem of “delay” mainly brought by unexpected occurrence, around which the agility components are developed. Based on a general description, the system also emphasizes the most useful components - the five agility enablers, which are validated later at conceptual level.

Finally, the achievability of this agile system is supported by validating the five enablers in both qualitative and quantitative evaluation. This result of this part is important in eliminating the ambiguity in believing such a system and enablers do exist and are recognized by construction practitioners. The interview and questionnaire survey yielded answers about agility, igniting the newly raised concept with more practical meaning and potential benefits.

4.2 Limitation and Future Research Direction

Though impressive as a conceptual framework, the agile construction management system needs more on-the-ground support from the following two aspects.

On the one hand, the enablers in the paper are divided into five major categories. It is natural to question if these categories are adequate and reasonable. In order to make this mechanism really work for guiding to solve delay problems, detailed and specific standards under each category should be established for the convenient application by construction practitioners.

On the other hand, the validation has not been carried out in a strong enough manner. Due to limited time and resource, the number of interviewee and questionnaire respondents is only good to confirm the possible effectiveness of the enablers, or the system. Data on certain enablers (such as Enabler 1: resource and productivity monitoring and trending) is apparently too small to represent the agreement among construction practitioners, which is also shown in the deviated opinions on certain enablers. Given the small number of samples and rough scale options in the questionnaire, it is still too early to tell if the result will be different when more respondents are involved. It would be interesting to continue a detailed survey with more people involved and a better defined scale.

Another topic worth future studying is how to fill in the void of the current "chasm" in the learning curve of agile construction management adoption. As is mentioned in the validation part, making the concept profitable largely depends on overcoming the fear of initial investment and execution difficulty. This may be achieved by both technical enforcement as "hardware" and psychological acceptance as "software", which deserves exploration from both technology and management perspectives.

APPENDIX A

Questionnaire on Possible Delay Reduction by Agile Enablers

Introduction

The purpose of this questionnaire is to conduct a survey about agile construction management to determine its potential effectiveness for reducing time delays in construction. The survey involves reading and answering questions about a case project. The information collected will remain anonymous, and will be used for academic purpose only.

Background Reading

Time delays are common in construction, and negatively impact the whole project performance. In order to reduce delays, an integrated solution – Agile Construction Management is proposed and considered suitable for dealing with the uncertainty of delay. As for specific agile methods, five "agility enablers" are identified, including: 1) Real time resource monitoring and productivity measurement; 2) Self-autonomous work teams with multi-functional crews; 3) Short-term planning along with concurrent execution of activities; 4) Continuous improvement based on learning organization; 5) Information technology integration.

Case Project Description

Selected is a UNM project that renovated 9937 square feet in Logan Hall for the clinical neurosciences core facility. The project consolidated and upgraded existing facilities, including several laboratories, data analysis spaces, collaborative working areas and building infrastructure. Based on the information provided by the UNM Office of Capital Projects (project owner), a conference room renovation was selected as the subject for this delay-reduction analysis.

The conference job consists of 14 activities which were subjected to two types of delays. One is a delay to the start date of activity. For example, the project was planned to start on Sep. 29, 2012 while it actually started on Nov. 8, 2012. All activities were subject to different late start. The other delay type is a delay during the execution of activities. Accordingly, the job was planned with an original duration of 26 days and it was finally completed in 50 days, with 24 days of delays.

The delays resulted from following reasons. 1. Changes by owners and designers to the original design; 2. Mismanagement of some activities as the general contractor pulled out the original superintendent to other jobs when work was only halfway done; 3. Activities could not proceed due to lack of design information (late response to submittals).

Questions based on selected delayed activities

1. The installation of the ceiling grid started on November 14. It was delayed by 46 days due to owner's changes leading to redesign of the work. To what extent do you think the delay could be reduced if the working team members had multi-functional capability and were empowered to contribute more to the pre-construction process?
Completely reduced
Significantly reduced
Somewhat reduced
Slightly reduced
Not reduced

2. For the above delay, to what extent do you think the delay could be reduced if there was a better short-term plan which allowed breakdown of activities and allowed starting those activities without disagreement on time?
Completely reduced
Significantly reduced
Somewhat reduced
Slightly reduced
Not reduced

3. For the above delay, to what extent do you think the delay could be reduced if all parties had worked collaboratively early on as a team and all learned from the similar cases in the past?
Completely reduced
Significantly reduced
Somewhat reduced
Slightly reduced
Not reduced

4. For the above delay, to what extent do you think the delay could be reduced if all parties had cooperated with each other by applying BIM upfront from the design phase?
Completely reduced
Significantly reduced
Somewhat reduced
Slightly reduced
Not reduced

5. The installation of doors was planned to be completed in 3 days. However, the superintendent was assigned to another project, leaving this project half-way done. During the turn-over process to the new superintendent, the workers lacked clear instructions, which caused a two-day delay. To what extent do you think the delay could be reduced if the project manager could accurately assign laborers and resources according to productivity records from previous activities instead of relying on field instruction by the superintendent?
Completely reduced
Significantly reduced
Somewhat reduced
Slightly reduced
Not reduced

6. For the above delay, to what extent do you think the delay could be reduced if the workers were self-motivated and capable of doing the task on their own even without instruction?
Completely reduced
Significantly reduced
Somewhat reduced
Slightly reduced
Not reduced

7. For the above delay, to what extent do you think the delay could be reduced if the contractor had predicted this change through a three-day short-term schedule review, and relocated a new superintendent in advance?
Completely reduced
Significantly reduced
Somewhat reduced
Slightly reduced
Not reduced

8. For the above delay, to what extent do you think the delay could be reduced if the contractor had learned a lesson from similar cases and responded more quickly to the change based on some prepared possible solutions?
Completely reduced

Significantly reduced
Somewhat reduced
Slightly reduced
Not reduced

9. For the above delay, to what extent do you think the delay could be reduced if the contractor applied some field control software to synchronize real-time changes with all subs for better communication?
Completely reduced
Significantly reduced
Somewhat reduced
Slightly reduced
Not reduced

10. The vinyl base was originally planned to be completed in one day. But due to the lack of design information (late response to submittals), the activity ended up lasting 13 days. To what extent do you think the delay could be reduced if the teams were more self-motivated to track the missing design information more frequently?
Completely reduced
Significantly reduced
Somewhat reduced
Slightly reduced
Not reduced

11. For the above delay, to what extent do you think the delay could be reduced if the contractor had learned a lesson from similar cases and responded more quickly to the change based on some prepared possible solutions?
Completely reduced
Significantly reduced
Somewhat reduced
Slightly reduced
Not reduced

12. For the above delay, to what extent do you think the delay could be reduced if the designer and contractor, at the very beginning of a project can work on the same platform like BIM which can convey real-time updates of change information to all parties?
Completely reduced
Significantly reduced
Somewhat reduced
Slightly reduced
Not reduced

APPENDIX B

Qualitative Interview Data Coding Sheet

As an important step of qualitative data analysis, initial data coding is conducted upon the written summary of all interview results below by highlighting data segments according to relevant meanings in different colors.

Enabler 1: Real time resource monitoring and productivity measurement

Recording daily resource (labor, equipment and materials) investment in the form of productivity as well as tracking productivity variance and weekly productivity trending could benefit projects from following aspects:

S:

- Regular productivity data tracking helps PMs stay proactive by moving controls forward, and makes projects better respond to changes;

- Productivity tracking helps identify changes early. When you find productivity goes down cross the line pre-defined, it raises attention to putting more controls on field operation, which makes project more adapt to changes;

- Real time monitoring and feedback of resource investments can bring time-saving. Using mobile software to track RFI (design-related changes) with real-time data can speed up RFI process;

- Real time productivity data collection and analysis helps contractors clearly know themselves on how to work in a more productive way (improved efficiency) from previous experience;

- Monitoring resources investment helps know why productivity variance occurred and supporting the mentality of being proactive for superintendents;

- Provide accurate results for building contractors' productivity database;

- When you know productivity trending, you can work on how to narrow the band of productivity variance and ultimately change and improve the trend (improved efficiency);

- Productivity tracking (actual quantity installed vs. estimate to judge our % of productivity) in conjunction with our two-week look-ahead keeps the crews to optimum size (improved efficiency);

W:

- Productivity data collection and analysis brings more paper work and thus time-consuming;
- It increases costs for hiring or training a specific person to do this task;
- If superintendents were assigned this task, there comes a fear of wasting their skills in regular on-site controls when they have to spend time on something they are not good at;
- "Learning curve" to train people to have related skills could be steep;
- It brings the additional of work of monitoring;

O:

- Contractor-driven changes will be the first to benefit from this approach;
- The rest of change categories could also benefit from it indirectly;
- It does not applicable for owner/designer changes (too many such changes are surprises);
- It is suited for field condition-related changes, material-related changes (keep eyes on market), and weather-related changes (if you find weather issues, you can adjust resource allocation to stay reactive to possible changes);
- It also works for owner-driven changes because data-based information can speed up communication between contractors and owners with less paper work. In addition, clearly knowing productivity makes contractors better react to "fast-paced" changes driven by owners;
- Support all types of changes because it helps form proactive mindset;

T:

- People tend to resist letting math or theoretical values to replace their empirical practical knowledge;

- People resist trying new things out of their comfort zone and don't truly believe or understand the value of this approach;
- It is challenging to develop a culture of embracing changes;
- Construction industry in general, still lacks relevant resources (standard tools and methods) to conduct productivity evaluation;
- The approach needs collaborative efforts of all team members. On the one hand, sometimes it is challenging to keep associated technologies available and consistent among all team members, which could cause issues of trade-interaction; On the other hand, it could be hard for GC to convince subs to it if they are in new relationship with each other;

Enabler 2: Self-autonomous work teams with multi-functional crews

Being agile can be reflected in labor/team organization. First of all, break down hierarchical structure to flat one by giving construction crews certain freedom to make their own decisions on project changes. In addition, train one worker with multi-functional capabilities so there is more flexibility to change work assignments to address tasks, if needed.

S:

- Time saving brought by responding to changes;
- It increases job site satisfaction for multi-skill trained crews in terms of higher individual productivity and motivation;
- Generally, pushing decision making to the lowest level of an organization makes possible a quicker and more responsive approach.
- Self-autonomous teams facilitate developing more collaborative atmosphere; help build awareness of communication;
- Multi-functional crews can provide expedient efforts based on educations in different trades;
- Properly managed labor increases working efficiency;

W:

- It is hard to implement this approach in the union environment where culture is based on hierarchy;
- It is hard to evaluate skill-level and determine paid-levels for multi-functional crews;
- It could damage individual productivity because it is hard for multi-functional labor to keep equal expertise in all skills so multi-functional idea is better implemented to form on team instead of individual basis;
- It could be much more costly to hire a person who is equally skillful in multi-trades;
- Individuals at the lower levels of an organization may not have all the information needed to make the best decision;
- Decision-making process could be slowed down in self-autonomous teams if information and knowledge are not shared/managed properly and no one is really leading;

O:

- It mainly benefits contractor-driven changes and all change categories indirectly;
- It is better applied to owner/designer driven changes and resources-related changes;
- Good for less-technical changes which does not require a worker with equal skills to work on multi-tasks;

T:

- Union is a huge obstacle to make this approach happen;
- There could be ROI (Return on Investment) issue (elusive benefit proof) when a multi-functional worker who is paid on the high-skill level has to do everything for a complete set of tasks from installing to sweeping floors;
- It brings a risk of losing some productivity and workmanship if you have a guy who is jack of all trades but no expertise for any one of skills;
- It depends on project types. For small residential projects, it is easier to assign people flexibly to handle changes; Large-scale projects prefer having workers with high

expertise in one trade to be more productive;

- Lack of well trained and knowledgeable personnel;

- It is hard to have multi-functional crews for public projects which require labors being separated into trades;

- Some rules/regulations make it difficult to happen. The rule of state wage rates requires workers to be paid according to what types of trades they belong to;

- The only restriction would be the number of journeymen and apprentices under one foreman that can be restrictive.

Enabler 3: Short-term planning along with concurrent execution of activities

To stay reactive during project execution, short-interval plan and review of schedule is commonly used in construction. In addition, overlapping activities is another means to adapt to changes and fast track project.

S:

- Short-interval planning makes resource data feedback more intelligent in a fluid jobsite and helps track activity individually (stay proactive);

- Save time in the long term even though it takes time for preloading people with these skills;

- Potential cost and time saving as short-term planning helps uncover potential problems and stay reactive to them;

- Short term planning can provide quicker responses to changes;

- Overlapping activities helps get work done efficiently;

- Improve collaboration and communication among team members;

- Huge advantages for developing a mentality of being proactive from daily work by revisiting yourself back to previous plans;

W:

- Short-interval plans might not anticipate long-term plans or meet long-term plans/requirements due to lack of thinking in a "big picture" of project objectives;

- Overlapping activities might cause negative ripple effects when successor activities are subject to rework due to the change of predecessor activities;

- Sometimes it is hard to have resources available and coordinate subs for sudden change recovery;

- Overlapping might be limited due to limited working spaces in case of trade congestion and stacking;

O:

- Benefit all change categories as short-interval planning can provide better ideas about how changes impact the project;

- Better work for materials and weather-related changes;

- Better used for owner-driven changes as it allows fast-paced responses;

T:

- Some people don't understand the value of this approach;

- Risks caused by overlapping activities without completely knowing sufficient information about previous activities;

- Concurrent execution of activities is good but sometimes limited by spaces and manpower to overlap as many activities as possible;

- It is challenging to ask team effort of all subs on this approach which requires a corporate culture of positive thinking/accommodating and embracing changes;

- Benefits could be limited because it probably does not do in-depth investigation (elusive benefit proof) of plans and schedules;

Enabler 4: Continuous improvement based on learning organization

One distinguished point of agile construction management is to learn from the lesson of changes and improve continuously from changes, which it is an accumulative and incremental process.

S:

- Avoid repeating same mistakes;

- Develops the culture of learning from changes by a partnering session before design with all key stakeholders to instill this agile idea upfront;

- It works better for large projects where you can learn and improve through a repetitive process;

- Brings higher quality and productivity based lessons learned from previous jobs;

- Potential time and money saving for learning from lessons in the long term;

- Become immune to changes by continuous learning from lessons;

- It is better used for pre-construction phase (enhanced collaboration) when owners and designers who are most likely to make changes sit together and learn from previous changes;

- It could become a good marketing method if you can show owners the value of this practice;

- Team benefit from sharing information, rewarding;

- A lot of continuous improvement is from input coming back from the field on better ways to perform the same task;

W:

- It is time-consuming and hard to see immediate benefits;

- It is hard to do such highly cooperative communication;

- It takes time and money to train people to understand and perform learning-based improvement;

- The associated learning curve is costly since it is hard to keep fixed personnel for construction projects;

- Possible fatigue from constantly looking to improve. There may be operations that are already honed and not in need of improvement.

- There are still no tools and regulations to make it a standard practice;

- Have to share risks among all entities;

O:

- Benefits for all change categories in the long-term;

- Good for owner-driven and environmental-driven changes if you learned from previous lessons;

T:

- Union could be an issue as it never in soul encourages making decisions dependently;

- Too much cooperative learning process could make some people feel less-valuable (resist new changes) when they are exposed to higher-skilled people; they can even fear losing jobs due to narrow-minded perception on it;

- People have rigid adherence to routine and resist to changes;

- Lack of education (training issue) of learning from lessons and collaboration;

Enablers 5: Information technology integration

Information technologies like mobile PM software and BIM have changed the way we manage and perform projects. But there is still room to fully integrate them to project management process.

S:

- It helps to make real-time decisions (responsive to changes) by using mobile equipment to communication with each other;

- It speeds up jobs and makes the process more flexible, for example by using mobile devices to track RFI process;

- Help to distribute information and recognize potential technical and management problems (stay proactive);

- Offer wider and efficient communication to track information in construction;

- BIM helps to collect data for facility management;

- Right now we are using GPS locating systems and BIM system to located conduit stub ups, gear placement etc.

W:

- It requires essential investment of extra time and money to train people;
- It needs to adjust/break original working process (adhere to routine);
- If people over-rely on 3D modeling, they could ignore the importance of personal check on site;
- It is not very cost-effective for small projects;
- Lack of managing data created by BIM (coordination issue);
- Too much information can slow down the construction process;

O:

- Work for every change category by integrating information technology;
- Work better for owner/designer-driven changes; because technologies promote communication with them;

T:

- Traditional construction workers might resist using new technologies because they do not have relevant skillset or stick on rigid adherence to routine;
- There is compatibility issue for different software (lack of resource) packages;
- A potential constrain for BIM is that BIM mainly benefits owners and helps them to manage buildings, but from contractor perspective, BIM is more like something providing extra value but not very essential to basic requirements in all cases or still fails to show very obvious proof of benefits for project controls;
- Some companies lack financial/technical capability to pursue these technologies;
- Probably be limited by the reliability of equipment or internet if you over-rely on web-based software tools to manage jobs;
- It is challenging to have all project members to participate and coordinate with each other on the technology integration;
- BIM should consist of two parts: information modeling and information management. If

you cannot manage data properly, models are useless. For example, if a modeler from any engineering discipline put the wrong parameters for building stuff being designed, it will cause interference with other disciplines. But the reality is no one wants to change their own model, which could result in delay, quality and communication problems;

Generic questions about Agile Construction Management

1) In your opinion, what is the prospect for agile construction management to be implemented? Will it finally become competence for companies, or be updated to a corporate culture?

- Agile Construction Management sounds a great idea but it still needs some initial proof of its benefits and values;
- Some agile enablers have already been implemented by large construction companies and require direct and clear initial proof of the benefits bought by these approaches;
- Demand on developing related standard codes of agile construction management;
- The agile idea sounds exciting since construction has too many constant flows. Prospect lies in promoting the agile ideas in the government-type agency that has the capability to do it because of the higher level power limit;
- Agile management is very good idea which requires owners to instill this idea as a part of project management philosophy/culture;
- Potential big opportunities in terms of advantages to the working process, creating collaboration, continuity and benefits to all project players;
- Stay agile to be competitive in this market environment;

2) What would be your main concerns about the extent that agile construction management is used?

- It could be hard to solidly prove the value of these approaches and educate people to use it. Probably they are not very applicable for hard-bid jobs;
- It is challenging to get cooperation from other members of the team;
- Complicated level of control required;

- Lack of uniform/consistent progress when people change out of projects;

- For any new concept, it is hard to accept and market it;

- Initial start-up expense in terms of cost, people, and time is high;

- Limited understanding of Return On Investment with the perception that benefits are better generated in short-term rather than long-term;

3) What other approaches could make a project more agile?

- Some approaches that can involve all project participant in the design process and ultimately form an overall plan rather than some sporadic requirements in the form of construction documentations;

- Put projects into a "TEAM" and get all parties involved and collaborate with each other before construction starts;

- Potential application area is agile supply chain. Proposed enablers explain people and technology-related approaches, there might be a need to get material suppliers involved and coordinate with other entities;

- Remain open-minded about new techniques, etc. and use critical thinking to analyze whether a suggested change will actually be effective. Be prepared to abandon something that doesn't work and move on to something that does.

- One of agile ideas: multi-functional capability should expand to management-level team but not only crew members; because only if people who make decisions have the agile ideas to do more cross-over things, they can really support more systematic agile approaches;

- Develop an agile project delivery system in terms of unified methods which break down the barrier between designers and contractors by promoting real partnership on only on project basis but on the whole industry basis;

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