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THEORETICAL DIGITALIZATION OF INFORMATION FLOW IN THE CONSTRUCTION SUPPLY CHAIN

Rui Liu[1] and Veronica Charmaine Chua[2]*

*Corresponding Author: ***Veronica Charmaine Chua*** ✉ veronicatanchua@yahoo.com

In the construction industry, waste always has been the main focus of numerous research studies around the world in recent years. However, most researches and studies give more attention on the waste of materials, which is only one of the physical resources involved in the construction process. However, physical waste reduction is no longer sufficient as efficient information flow is the key and lifeblood to the success in this era. The main objective of this paper is proposed a theoretical digitalization process of construction supply chain's information flow and on how lean principle is achieved at the end. In-line with the theoretical digitalization process of the information flow, the author briefly discussed how lean construction supply chain in terms of information flow and sharing is achieved.

Keywords: Construction Supply Chain, Digitalization, Lean, Lean Construction Supply Chain, Information Flow

INTRODUCTION

In the construction industry, waste always has been the main focus of numerous research studies around the world in recent years. However, most researches and studies give more attention on the waste of materials, which is only one of the physical resources involved in the construction process. This seems to be related to the fact that most studies are based on the conversion model, in which material losses are considered to be directly equal to waste (Aziz and Hafez, 2013). Formoso *et al.* (2002) stated that many people in the industry have considered wastes are directly associated with the debris removed from the site and disposed of in landfills, and they suggested that the main reason for this relatively narrow view of waste is perhaps the fact that it is relatively easy to see and measure (Formoso *et al.,* 2002). The main focus for those conventional material waste studies in construction is seen to be restricted to physical waste or material waste in construction and/or the specific impacts due to the physical waste itself (Aziz and Hafez, 2013).

However, massive construction projects mean that there are different kinds of wastes and

[1] North China Electric Power University.

unnecessary cost due to construction industry's fragmented and adversarial nature that led to poor communication and inefficient information practices which have contributed to the emergence of dysfunctional construction supply chain (Love, 1996). This means that there is a lot of inefficiency and ineffectiveness in the current construction supply chain practice in information sharing that generates majority of the wastes and costs. Limited studies in construction suggest that poor supply chain design regularly increases project cost by ten percent (10%) (Kumar, 2001), and this estimate is on the conservative side. Project duration will be similarly affected, as delays in information transfer are unavoidable. In an integrated construction supply chain, information is shared and becomes available among the members and thus, enhances supply chain visibility, which avoids information delays and distortions.

Since information sharing is the key to the success of construction supply chain as it enables the project participants to make a decision that crosses both systems and companies (Hu, 2008). Information flow in the current construction settings is very inefficient due to the fact that majority of the information are travelling through an inefficient and unorganized fashion. It shows that in this information era, the use of Information Technology (IT) or referred to as digitalization in this study, construction industries have not utilize digitalization sufficiently, let alone use it to achieve lean in construction supply chain.

Therefore, digitalization is a must in enhancing the information flow, which is considered as the lifeblood in construction supply chain. Digitalization of information flow and sharing can greatly increase the efficiency and accuracy of data flow within the construction supply chain from a system perspective. Through collaboration of all the participants within a construction supply chain, digitalization of information in the construction supply chain would equate to the reduction of workload, time wasted and running costs. Digitalization will reduce residual information waste and data inaccuracy through cost cutting by means of reducing human error in the process of digitalizing information flow.

LITERATURE REVIEW

The aim of literature review in the paper is to verify the relevant theories as a knowledge base and help the reader to understand the relevant concepts and theories, in terms of lean, construction supply chain and Information Technology in construction supply chain. Those theories have an influential contribution and widely used in diverse industries, not only in construction.

Lean

A popular misconception is that lean is suited only for manufacturing type of companies as it originates from such. However, lean can be applied in every business type and every process. It is not a tactic or a cost reduction program, but a way of thinking, discipline and execution for an entire organization with overhead cost reduction as a top priority. Businesses in all industries and services, including healthcare and governments, can use lean as a way they think and execute in their organization. According to Lean Enterprise Institute (LEI), many organizations choose not to use the word lean, but to label what they do as their own system, such as the Toyota Production System (TPS) or the Danaher Business System. They do this to drive home the point that lean is not a program or short term cost reduction

program, but the way the company operates. In addition, the term transformation or lean transformation is often used to characterize a company moving from a traditional way of thinking to lean thinking. It requires a complete transformation on how a company conducts business, which takes a long-term perspective, perseverance and discipline.

According to LEI, the core idea of lean is to maximize customer value while minimizing waste or simply, it means creating more value for customers with fewer resources. A lean organization understands customer value and focuses its key processes to continuously increase it. The ultimate goal is to provide perfect value to the customer through a perfect value creation process that has zero waste. To accomplish this, lean thinking changes the focus of management from optimizing separate technologies, assets, and vertical departments to optimizing the flow of products and services through entire value streams that flow horizontally across technologies, assets, and departments to customers.

Construction Supply Chain

When a construction supply chain is being defined from the lifecycle of construction project side, it will be a series of functional activities in which setting the owners' wants, needs, perspective and requirements as a main objectives which is, begin with project requirements, define the project scope, funding and designing the project, building the actual project, turn over of the project and maintaining the project until reconstruction or demolition.

Whereas, when the construction supply chain is defined from the construction company's perspective, it is the meeting of the construction supply chain to the owner's requirements and expectation, assigning the contractors as the core participants of information flow, logistics and cash flow and to form a construction network together with the suppliers, sub-contractors, architects and owners.

In terms of structure and function, the construction supply chain is characterized by the following elements (Vrijhoef and Koskela, 2000):

- It is a converging supply chain directing all materials to the construction site where the object is assembled from incoming materials. The "construction factory" is set up around the single product, in contrast to manufacturing systems where multiple products pass through the factory, and are distributed to many customers.
- It is, apart from rare exceptions, a temporary supply chain producing one-off construction projects through repeated reconfiguration of project organizations. As a result, the construction supply chain is typified by instability, fragmentation, and especially by the separation between the design and the construction of the built object.
- It is a typical make-to-order supply chain, with every project creating a new product or prototype. There is little repetition, again with minor exceptions. The process can be very similar, however, for projects of a particular kind.

Furthermore, construction supply chain consists of the construction lifecycle processes and all construction participants, the construction lifecycle processes are from the decision and concept phase, design phase, construction/ implementation phase to transfer phase, maintenance phase, and demolishment of the

engineering, and all construction participants are those organizations which are involved in the construction lifecycle processes, such as the clients/owners, architects/engineers, general contractors, subcontractors, suppliers, and consultants. Construction supply chain is a network of multi organizations whose performances depends on the comprehensive information flow among clients, architects/ engineers, general contractors, subcontractors, suppliers, and consultants (Hu, 2008).

Information Technology of Construction Supply Chain

Traditional construction supply chain relies on a "fly-by" assembled team by the contractors and the suppliers to manage the whole supply chain. This type of approach to the construction supply chain has proven to be inefficient and often leads to miscommunication. Digitalization of construction supply chain is about the automation of all the manual process involved in the system and therefore, reducing the amount of human intervention in the supply chain.

Nicolini *et al.* (2001) pointed out the inefficiency of centralized coordination system in managing interdependencies within a construction supply chain. In order to facilitate information sharing, they suggested a cluster, which is a temporary organization consisting of designers and suppliers, to support intensive collaboration between different disciplines. Clustering design helps minimize interfaces, which in turn, facilitates communication transparency (Nicolini *et al.*, 2001). In terms of this type of collaborative design, Bogus *et al*. (2000) claimed that design team should be expanded such that it includes contractors, subcontractors, and material suppliers. They described that traditional constructability concepts have contributed to improve the flow of construction process but they should not be limited only to designers and contractors. They expected however that communication will be the most difficult part but recent advances in information technology could make it easier for them to communicate (Chopra and Peter, 2001).

Arbulu and Tommelein (2002) stressed the importance of coordination and communication between the participants in the supply chain using the design of pipe supports as an example. They claimed that in practice, real-time feedback and pull of materials to the site seemed to be missing in this design process (Arbulu and Tommelein, 2002). In addition to the information sharing in the design phase, Chua *et al.* (1999) and Choo and Tommelein (2000) extensively discussed the planning and the scheduling perspective of information sharing. In the distributed Integrated Production Scheduler (IPS) model, all the members of a project are responsible for executing schedules and providing relevant information so that all the process is clearly visible to the others (Choo and Tommelein, 2000; Chua *et al.,* 1999).

Choo and Tommelein (2000) emphasized the importance of well-structured communication and coordination in a dynamic and complex project. They developed a database program called Work Move Plan in order to automatically create look ahead plans and weekly work plans(Chua *et al.,* 1999). Both of the approaches allow project participants to share the latest schedule information and to propagate conflicts if there is any.

Contrary to facilitating information sharing within the given process, Vaidyanathan (2002)

redesigned the information flows in the house reconstruction market from a large retailer's perspective. In his framework, the retailer takes control of information distribution in order to enhance the accountability to the end customer (Vaidyanathan, 2002). Similarly, Taylor and Bjornsson (2002) proposed the "e-chain" framework to have benefits from information and material flows. They also pointed out that business must be willing to share key data, and disparate legacy systems have to be integrated, to exchange information seamlessly (Taylor and Bjornsson, 2002). For integrating heterogeneous legacy systems in construction, O'Brien *et al.* (2002) proposed Scalable Extraction of Enterprise Knowledge (SEEK) toolkit. SEEK provides structured approaches to integrate semantically heterogeneous information using wrappers and access layer architecture (O'Brien *et al.,* 2002).

Although various studies have shown the different root cause of the problems in construction supply chain and different approaches to solve them, it is difficult to find any exertions of developing detailed approaches for obtaining real-time information in construction supply chain management. Furthermore, none of them has mentioned the issue of interoperability, which is a critical problem in implementing their solutions in practice. A construction supply chain is a dynamic supply chain where the customers' needs and requirements are continuously changing, as in military logistics (Simon, 2001). In this case, rapid deployment is more important than optimization, and information technology is needed to make information visible in real-time as they occur (Kumar, 2001).

Analyzing the building industry as a whole, it showed that the construction industry is slowly adapting to the digital age (Chua *et al.,* 1999). The majority of participants in the industry are using one or more digitalization tools to organize their activities (Jacoben and Obro, 2010). The problem is that when general contractors receive digital information they do not pass them on to the construction site in digital format. Instead they print the information that makes it difficult for the construction management to have a complete overview of the newest information. Thus, the effort of implementing digitalization in construction supply chain is mainly focused on the general contractor, the administration level.

KEY ISSUE

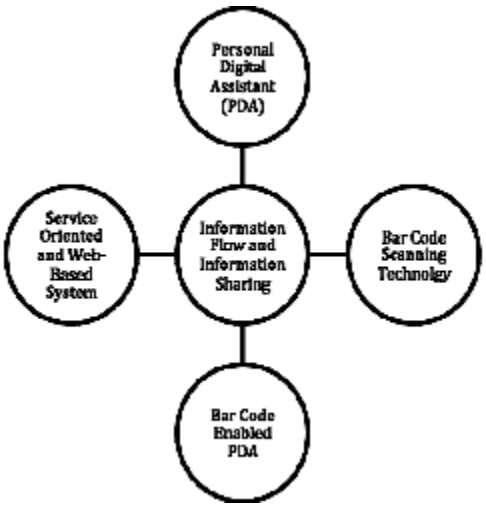
In the construction industry, supply chain integration is technically challenging to both programmers and analyst due to the adversarial and fragmentation nature of the industry and the complexity of the construction build. Cheng *et al*. (2010) stated in their study that information, applications, and services are loosely distributed among participants with a wide range of hardware and software capabilities. In addition, participants of a construction project are unwilling to share information most of the time for the reason that they cannot build trust due to the obstruction of construction projects' temporary nature With that say, a secure, modular, and flexible system that can aggregate scattered information and share that information across applications is highly desirable (Chopra and Peter, 2001). Thereafter, Cheng *et al.* (2010) proposed a service oriented, web-based system that can provide both coordination of supply chain, web portal and open source technologies. These technologies enable the software system to provide an economical and customizable tool for integrating supply chain partners with a wide range of computing

capabilities, which include integrating, and managing information from project partners (Chopra nad Peter, 2001).

Construction project control intends to effectively obtain real-time information and enhance dynamic control by utilizing information sharing and connecting involved participants of the projects to reduce construction conflicts and project delays (Tserng *et al.,* 2005). However, application of the construction project control system in job sites cannot be considered efficient since using paper-based documentation such as notebook in a harsh environment like construction site is not particularly a conventional practice. Moreover, paper-based documentations of the site processes are ineffective and cannot acquire the response from the office and project control center on time. As a result, integrating promising information technologies such as Personal Digital Assistants (PDA), bar code scanning, and data entry mechanisms, can be extremely useful in improving the effectiveness and convenience of information flow in terms of material in construction supply chain control systems (Tserng *et al.,* 2005). Bar code scanning is suitable for different construction applications, which provides cost savings through improved speed and accuracy of data entry. There is a proposed system which is a web-based system utilized to effectively integrate general contractors, subcontractors, and suppliers so that construction's purchases are made on-time and distributed in the right quantities and to the right locations. Moreover, paper-based documents are being superseded by integrating PDAs and bar code systems with the construction supply chain system to solve the problem in retrieving the information. PDAs can extend the supply chain software systems to construction sites. Meanwhile, the efficiency of data collection can also be improved using automated bar-code-enabled PDAs to enter and edit data on the job site.

Through the help of web technology and mobile devices as shown in Figure 1, the construction supply chain system for general contractors can become the great potential to increase the efficiency and effectiveness of information flow

Figure 1: Existing Information Sharing and Information Flow Solutions



and information sharing, thereby streamlining construction processes with other participants. However, existing solutions of the information flow and information sharing problem focused only on gathering the information regarding materials and equipment of the construction supply chain. They are intended for eliminating physical wastes and improving material management, yet, neglecting the most important key issue behind all the unnecessary wastes and costs, information flow of the whole construction supply chain. Thus, this problem remains unsolved and needs further study.

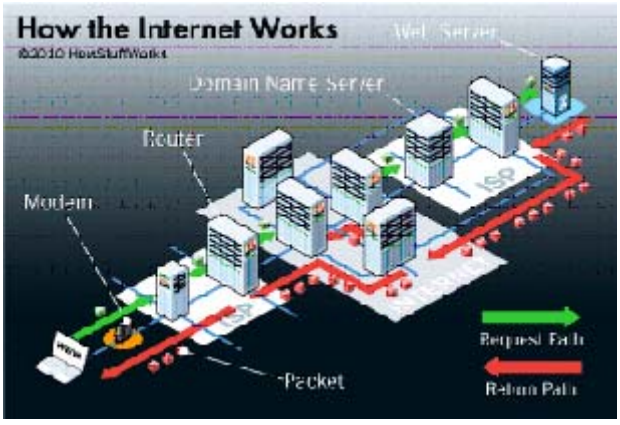
THEORETICAL DIGITALIZATION PROCESS

The internet works as a global connection of computer through deep sea cables usually crossing the oceans of the world. Satellite communication is possible but with limiting speed and bit loss, people resorted back to physical cable laid on the ocean floor. These massive heavily shielded cables that are on the ocean ground are densely pack fiber optic cables that can transmit signal at 99.7% of the speed of light. Internet service providers usually have direct access with these deep-sea cables to provide connection to the people. In Figure 2, it shows how the internet works in a very simple way.

Domain name server or DNS provides a website its numerical identity throughout the world. When a user wants to visit external website such as Google or Yahoo, the internet service provider of the user will look up the domain name throughout the servers around world and connect to it. By then, the user and the website can interact in a seamlessly smooth way. The use of the internet in the improvement of supply chain is endless as communication is getting very efficient and effective.

The way this would be applied to digitalization is very important as there would be multiple servers that needed to be built in the general contractor to handle incoming connections from different construction supply chain parties. The improvement centers on the general contractor that would create his own server and platform for the software in which Engineers, architect, general contractor, suppliers and most importantly, the client can connect and exchange necessary information over the internet. This type of setup would enable the whole construction supply chain to have a seamless connection to

Figure 2: How the Internet Works (HowStuffWorks, 2010)



each other by setting up a platform in which everyone can use and see anywhere.

There are two ways to setup the digitalization of the construction supply chain. One is though the web in which the general contractor would need to setup his domain name and register the website so that the server can operate globally by having a specific domain name registration and the other one is through the use of a Virtual Private Network (VPN). The author chooses the method of improvement by setting up the server in the general contractor and having it registered globally as this would enable the use of mobile phones and Personal Digital Assistant (PDA).

Parameter Setup of Digitalization in Construction Supply Chain

Information technology in the Philippine construction supply chain has come into a minor slump and has slowed down progressing after the introduction of the use of email. Most supplier communicate through the use of email, cellphone, telephone, fax and most importantly, physical meetings. The setup of the digitalization process is that all the information regarding the construction is transmitted through direct connection through the VPN. ERP systems in manufacturing are all about the connection and integration of each steps of the manufacturing. The digitalization of construction supply chain however, circles around the integration and better connection of each supplier to the general contractor. A system which members of the construction supply chain can access anytime and anywhere is vital to the improvement of the construction supply chain.

In Figure 3, it shows the sequence on how a process is initiated from the client's request to the technical management of the construction. The parameters of the digitalization of the construction supply chain would revolve around the information listed in the image. The engineering section of the sequence graph would be handled by both engineer and architect as both of them need to coordinate with the design and structural integrity of the building. Both suppliers, who are supplying the construction with raw material needed for the construction, and the general contractor, who is managing the delivery schedule and the quantity needed, handled the procurement section. Construction is also handled by the general contractor and the project manager. Commercial and technical

Figure 3: Process Sequence

management is handled by the project manager also as they are the one responsible for any faults in the structure.

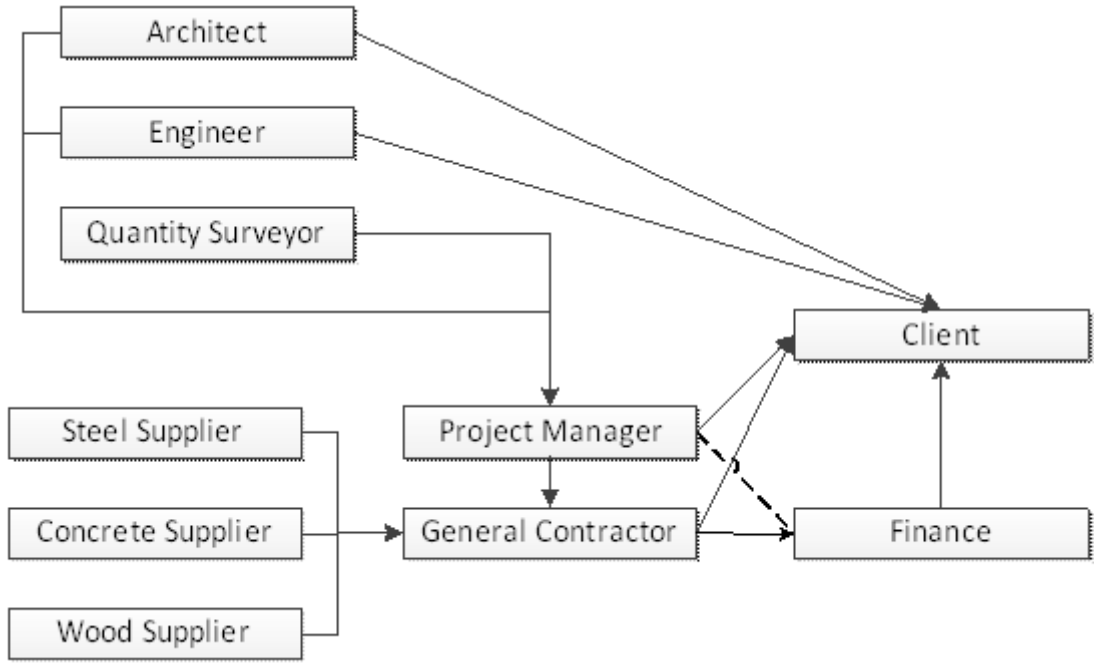
Information transfer of these data is the main focus of this study. These information will travel through the system of the general contractor through the internet. This kind of information delivery method will require cooperation of each and every participant in the construction supply chain, as the general contractor will greatly depend on the accuracy of the information in the system. Additionally, the elimination of communication through digi-manual method such as Email, text, calls and physical meetings and the like will greatly improve the efficiency of the whole construction supply chain through effective communication.

Digitalization of Communication Methods

The digitalization of a construction supply chain is often regarded as cloud construction management since all the information in the construction project is in the cloud. The application of IT in the construction project will minimize transfer time of information and will yield a better information flow. With this, lean construction supply chain management will be achieving through the efficiency and effectiveness of the information flow.

Below, Figure 4 shows a typical layout of construction supply chain that involves various component manufacturers, sub-contractors, architects and engineers, and executed by a single main contractor. It is the typical relative connection of the construction supply chain participants in which stretches out up to the component manufacturer, who are the suppliers in this scenario. All the information transfer in all processes is done one at a time. Meaning to say, that one member must reply and confirm before the process proceeds. In this traditional model of

Figure 4: Traditional Construction Supply Chain



the construction supply chain tends to have a lot of miscommunication and delays due to the fact that the suppliers and the sub-contractor level are fragmented and does not have a communication. The effectiveness of digitalization in a construction project is obstructed by the inability to share electronic data between construction participants. Lack of interconnectivity means that there is a lot of inefficiency and ineffectiveness coming from miscommunication in the current construction supply chain practice in information flow and sharing that takes majority of the wastes and costs. Additionally, in the sequence flow model of the steel supplier in earlier chapter shows that the single path processing of request requires too much time and creates unnecessary delays in terms of transmitting information to each other.

The digitalization of the construction supply chain should be applied at the general contractor's level since it is the one who oversees every movement in the construction project. When the main contractor's supply chain undergoes digitalization, complete data transparency is a must from all subcontractors, suppliers, and components manufacturer involved in the system. The information transparency is very critical for the digitalization of supply chain to work because all of the changes in the construction will be an unanticipated move. Engineers, architects and the client are the main sources of possible changes in the construction as the general contractor is only the executor of plans.

Information highway must be created in order to achieve lean construction supply chain through digitalization. With the technology today, cloud storages and cloud computing enabled a wide area of improvement in the aspect of construction.

The internet will enable all the key people in the construction project to see the actual supply chain of the contractor. Every changes requested by the client will be acknowledge by the project manager who has direct access to the cloud can give a feedback more quickly and more accurately if the changes were feasible or not. Figure 3 is the structure of the cloud system that will hold the information of the entire component manufacturer and sub-contractor's data.

Changes in the construction project make by the clients, engineer and architects can be easily evaluated by the contractor on what will be the effect on the current cost and project schedule. The digitalization of the construction supply chain can accommodate changes easily because of the availability of "real-time" information and project timelines. Wastages are avoided through the availability of simulation included in the digitalization process. When a change happens in the higher level, data information will be quickly available to all the sub-contractors and component manufacturers for them to be able to adjust accordingly to the changes and thus, eliminating the risk of information mishandling.

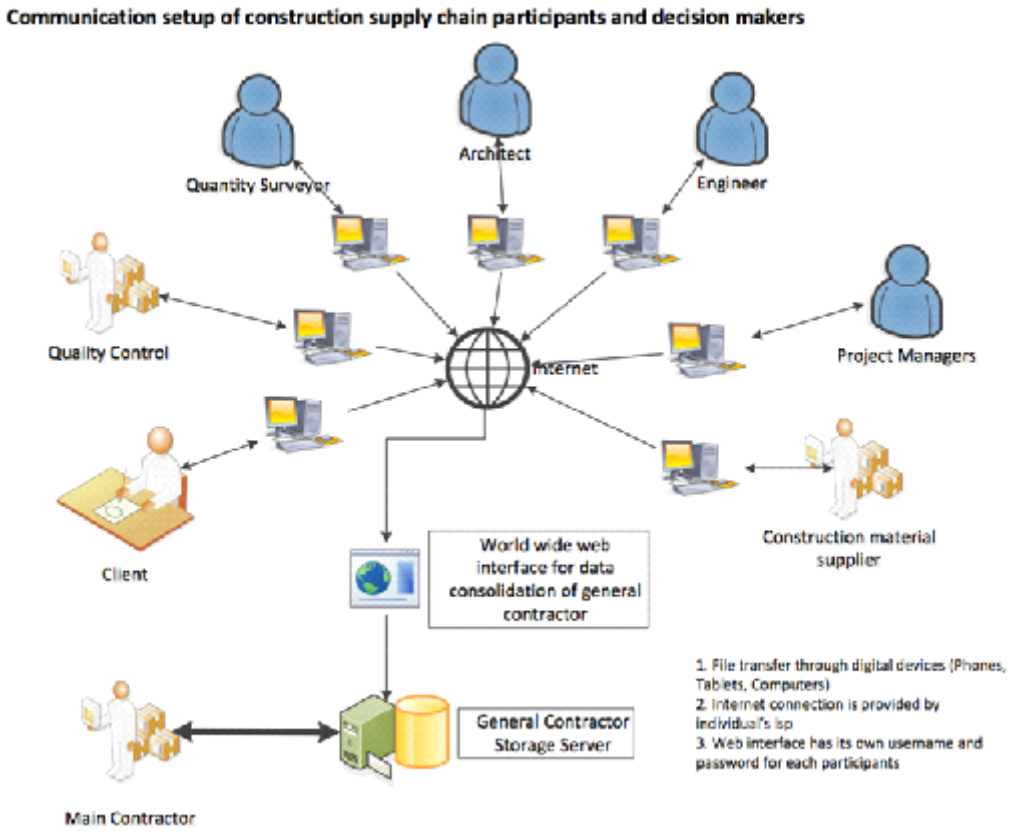
Participants of the construction supply chain will use the internet to connect to the general contractor's website and login with their credentials in order to key-in information. The structure of the internet is similar to that of the SMS messaging used earlier for communication. All participants will have to connect to the internet through their respective Internet Service Providers (ISP) and using that, they will have access to the website of the general contractor that is used for gathering information. ISP's will connect the different construction supply chain participants to the general contractor's server for input of information.

Improved data exchange through internet has enabled a smooth company to company communication and collaboration. Figure 6 is an example of a typical Information Technology backbone in supporting the digitalization of a construction.

In a typical IT setup of the construction project, two server storages at least are required for the digitalization of the whole construction supply chain. Primary server is for the client, suppliers and the engineering team to connect to through their local ISP and the secondary server is for the access point of the server of the general contractor.

The data coming from the suppliers will be their own production schedule, delivery schedule, quantities of components and output capacity. These information are needed by the contractor in order for them to have a tentative execution date and timeline in the construction project itself. The transparency of the information from the supplier to the contractor will ensure a lean supply chain by reducing the risk of information inaccuracy during transfer and by reducing the amount of time the data being transferred. By introducing a real-time update of the production schedule of the component manufacturer, sub-contractors can project their timeline more accurately. When all the information in the supply chain has been digitalized, the risk of incorrect information is significantly lessened.

Figure 5: Structure of the Cloud System



The internet is where the interconnectivity of the server happens through the help of multiple countries connecting to each other through various means (Satellite, Deep Sea Cable etc.). Figure 5 is the structure of the cloud system in the supply chain. In which, it shows that once the data has been transmitted from the supply chain participants to the general contractor's server, all the information regarding delivery schedule, lead-time and production capacity can be easily analyzed by the general contractor. The advantages of having a cloud-based digitalization are those data management will be easy and will have a real-time monitoring system through the interconnectivity offered by the internet. The supply chain of the project will be easily managed if the information is centralized. Digitalization of the construction supply chain will give additional control to the general contractor in terms of monitoring and project execution. Engineers, architects and project manager can easily monitor the whole construction supply chain and how their decisions will affect the whole construction.

Network Setup of the General Contractor's Server

The current network setup of the general contractor is the normal computer setup without the firewall and the servers. With the addition of the servers, the general contractor would create an access point for all the supply chain participants. This setup is currently employed by

Figure 6: IT Backbone of Digitalization in Construction

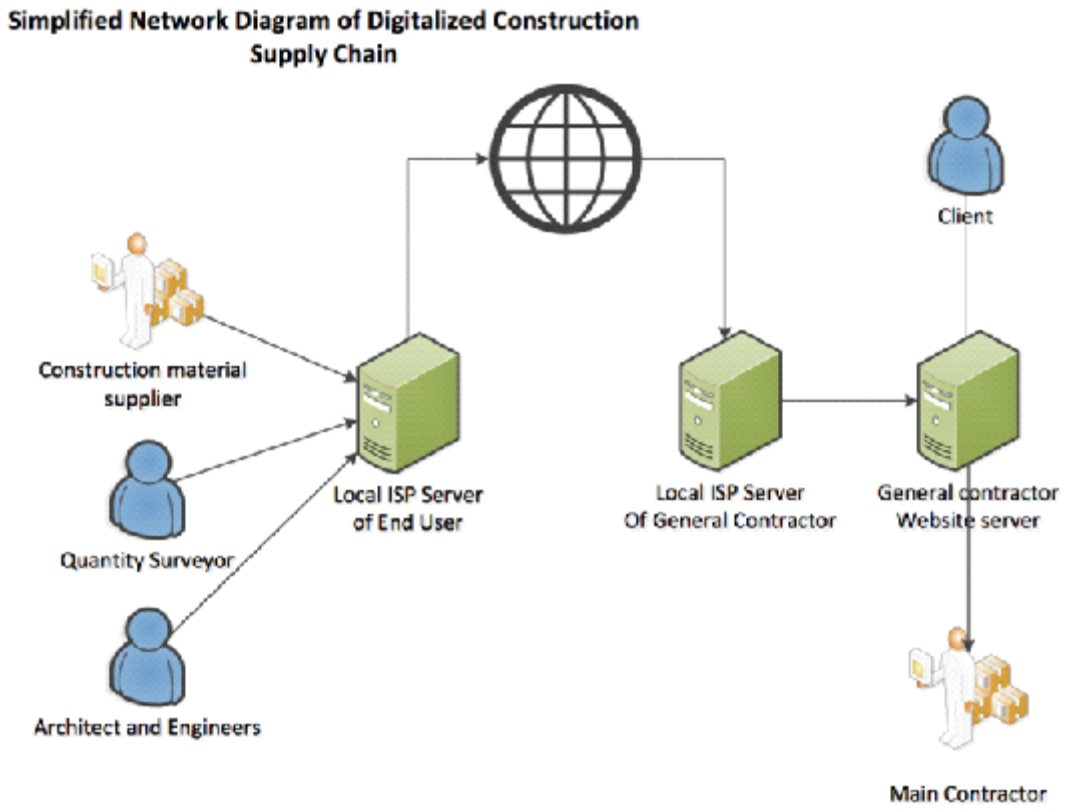
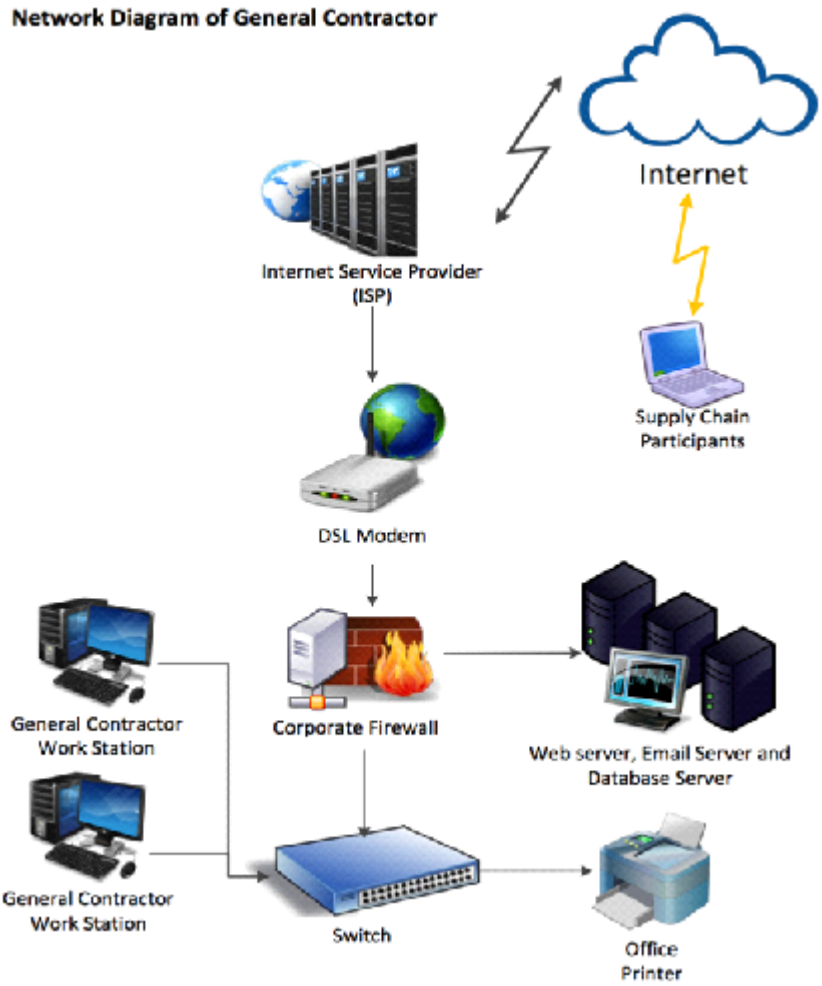


Figure 7: Network Diagram of General Contractor



many small businesses because of the ease of use and the availability of networking components.

On the side of supply chain participants, accessing the website of the general contractor can be done by connecting their devices to the internet and navigate to the website of the general contractor. Once the supply chain participants connected to general contractor's domain name through the internet, it will then pass a layer of security called the firewall. The firewall is the first line of defense that a company uses to protect their network. Once the client has gained access to pass through the firewall, it can now connect to the server of the general contractor to input data necessary for the construction supply chain (Figure 7).

LEAN CONSTRUCTION SUPPLY CHAIN

The idea of lean construction supply chain combines two advanced ideas: lean and construction supply chain. In 1992, Lauri Koskela submitted a report named "Application of the New Production Philosophy in Construction", in which lean was introduced to construction industry for

the first time. Nowadays, over 15 countries including UK, USA, Finland, Singapore, Australia, Brazil and so many more, have embraced and applied lean to their construction industries. Moreover, numerous studies have proven that application of lean in construction supply chain has significant benefits like the shortened construction time, the decreased engineering changes and claims, low project cost and the like.

In order to achieve the objective of the paper, the author proposed the digitalization of communication method within the supply chain to achieve real time communication between the participants and the delay free information flow and sharing. Moreover, The ultimate purpose of lean construction supply chain is to achieve cost effective collaboration among all construction supply chain participants including tendering, design, consulting, purchasing, supplying, construction, final completion and inspection, the delivery to the client, etc., therefore satisfying the client, getting rid of all the wastes, and strengthening the overall competence of the construction supply chain can also be achieved as the end result.

Path Toward Lean Construction Supply Chain

Identification of the Waste in Construction Supply Chain Process

There is historical pattern for starting with production activities; Toyota started its lean work by focusing on its shop floor. Thus, starting lean activities with construction site process also has a good rational basis because value is added, which is from the client's standpoint, during the construction process. Finally, the strict value definition that was used for the site studies (Walbridge-Aldinger, 2000) provides a lens through which one can start to identify waste in the site processes (Walbridge, 2000).

In this paper, achieving lean also aims to eliminate wastes that are caused by inefficient information flow and sharing that are found in construction supply chain These wastes commonly are waiting time (refers to waiting people, material or information for next operation), transport, inappropriate processing, unnecessary inventory, unnecessary motion (ergonomics, bending, reaching) and product defects. While from the perspective of the information flow, these wastes are transport time of information between participant, inventory due too much, too little, or erroneous information, motion of workers, wait time between process steps, over-processing that places high attention on low-value activities and over-production that which places the priorities on the wrong activities, drivers, or values, and defects or activities that are not directly related to needs.

Elimination of the Waste

After the wastes have been identified, the next step is to eliminate them. A given kind of waste like time waiting might have one or several different causes; and one has to identified and understand the root cause to eliminate the said waste. In this case, some of the causes of the wastes are timeliness, availability and accuracy of the information. These causes are eliminated through the proposed digitalization, as it offers a centralized platform for information to flow and sharing. Hence, the wastes are also eliminated in the process of eliminating the causes.

Achieving Lean Principles

Once the wastes are eliminated, lean principles can now be applied. In lean, there is five principles namely value, value chain, flow, pull and

perfection that we need to achieve. They are also just like five-step thought process for guiding the implementation of lean to the construction supply chain. The lean principles can only be applied fully and effectively in construction supply chain by focusing on improving the whole process. This means all participants have to be dedicated, involved, and work to overcome hindrances that may surface from traditional contractual set up. They are discussed in detail on how they are being applied and achieved.

Value: This principle is about establishing the expected value from the end users or customers' point of view. Value is something that the client particularly demands and is prepared to pay for. But people spend the majority of their time doing something other than adding value. Studies show that people tend to only add value to a product or service for just 5% of the time. The rest of the time people spend in wasteful pursuits; they are waiting, reworking, transporting, moving and a swarm of other wasteful activities that the customer does not consider to be something that they should pay for. By clearly defining value the end customer's perspective, all the non-value activities or waste can be targeted for removal.

In the paper, the value is to deliver the information the client needs on time or in a span of time that is acceptable for the client. This is achievable through digitalization to deliver the value that what it is that the client wants and not what one think the product (information) is but what is value in his eyes.

Value Chain/Value Stream: In this principle, it is about mapping out the value chain and eliminating the non-value adding activities. In other word, it is mapping out the value stream, which is the series of interrelated processes that produce the value. Within lean, we are looking to eliminate or to minimize those non-value adding activities and we are observing at the value stream from the viewpoint of the product or value, not observing at individual divisions or even organizations. Additionally, in lean, identifying the value stream is the how value will be realized and established when and how decisions should be made. Mapping the value stream indicates when the information necessary to meet the client's requirements will be available and when it will be required; and through utilizing digitalization of the process's information flow; the information can now become readily available when it is needed with accuracy.

Flow: This principle aims for one-piece continuous flow and synchronize all activities. What we are trying to achieve with this principle is the flow of products or value from one activity to the next, each activity being a value adding activity. Never delays a value adding activity by a non-value adding activity, where possible have these done in parallel to the value adding one. It just simply means to make the value-creating activities occur in tight sequence so the product will flow smoothly toward the customer.

With help of the theoretical digitalization process, the goal of one-piece continuous information flow shows that it is feasible and viable. There will be no more human error or less human error due to the information sharing. Wastes such as transport time of information between participants and wait time between process steps will surely decrease as well.

Pull: This principle is about understanding the customer needs on one's service and then creating the process to respond to the needs. Such that one gives only what the customer wants

when the customer wants it. In other word, it is just do not make anything upstream until needed or let customers pull value from the next upstream activity.

In terms of information sharing and flow, one will require accurate data/information on time when one needs it. That is why, through the proposed digitalization process, the processes can provide the information required by clients whenever they ask for it.

Perfection: It is about increasing rate of flow and competing against perfection. Creating flow and pull starts with fundamentally restructuring individual process steps, but the improvements become truly significant as all the steps will connect together. As a result, more and more layers of waste become visible and the process continues towards the theoretical end point of perfection, where every asset and every action adds value for the end customer. In short, as value is specified, value streams are identified, wasted steps are removed, and flow and pull are introduced, begin the process again and continue it until a state of perfection is reached in which perfect value is created with no waste. At the end, this idea is able to achieve for the chosen processes, especially after the proposed digitalization process.

CONCLUSION

The effectiveness of information and data acquisition influences the flow and sharing of information between the participants. However, current practice in the construction supply chain on how they obtain and share the information causes the duplex, confusion and lack of information and time delay. In other words, existing ways of processing information is not only time consuming and costly, but also reduce the performance and accuracy of information acquisition. Furthermore, construction participants normally depend on interactions over the telephone or fax machine, e-mail and courier to communicate with each other. Consequently, information sharing is often misunderstood and ineffective.

The digitalization of information flow is critically essential to the enhancement of the current supply chain network of the construction. When there is an increase in the effectiveness and accuracy of data transfer involved in the construction information supply chain, various costs due to errors, delays and rework are greatly reduced through the digitalization. Accurate data transfer from one person to another in a real-time environment will enable the members of the supply chain to coordinate and collaborate better. It will also grant additional flexibility and faster execution of changes, as all the concerned entity will be immediately notified when a change in the construction project has been initiated. Additionally, decision making entity can quickly access necessary information regarding the construction and get in touch with the concerning partner regarding the decision.

Through the proposed collaboration of information and data critical to the construction supply chain, digitalization of construction supply chain's information flow would reduce the effort and waste due to information inaccuracy, cost cutting by means of reducing human error in the process of information transfer. In the paper, lean construction supply chain is the end result of a successful theoretical digitalization of the construction supply chain in terms of information flow and achieving the lean principles. Even

though applying lean principle into supply chain already become a success factors to better meet clients' needs and improve the information flow efficiency. However, how efficient is depending on how is actually performed. Additionally, successful implementation of lean construction supply chain will require a holistic view that included not only shorten one session of the supply chain but also integrating every parts and participants as a whole. The lean principles can only be applied fully and effectively in construction supply chain by focusing on improving the whole process. This means all parties have to be committed, involved, and work to overcome obstacles that may arise from traditional construction supply chain arrangements.

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Hyderabad, INDIA. Ph: +91-09441351700, 09059645577
E-mail: editorijmrbs@gmail.com or editor@ijmrbs.com
Website: www.ijmrbs.com