CHALMERS

Vendor Managed Inventory in the Swedish Construction Industry

Master's Thesis in the Master Program of Design and Construction Project Management

DAWEI YU

Department of Civil and Environmental Engineering
Division of Construction Management

CHALMERS UNIVERSITY OF TECHNOLOGY
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Department of Civil and Environmental Engineering
Division of Construction Management

Chalmers University of Technology
SE-412 96 Göteborg
Sweden
Telephone: + 46 (0)31-772 1000

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ABSTRACT

In the construction sector wastes and problems concerning logistics and supply chain management are widely found, and they are some of the important interfering factors for improving efficiency and productivity within the sector. Vendor Managed Inventory (VMI) is a well developed and adapted approach for logistics and supply chain managements in other industries, such as automotive. This thesis is aiming to explore the capability of VMI adaptations in the Swedish construction sector. Semi-structured interviews are executed to obtain practical supports for this research in addition to relevant theoretical frameworks. Interviewees from different parts of supply chains are chosen to obtain essential reflections and enhanced credibility of empirical findings. Construction companies are interested in trying the VMI approach with strategic item suppliers as they could gain more benefits; meanwhile, construction companies have negative opinions with non-critical item suppliers, since they are currently enjoying their role in the relationships with this type of suppliers. Suppliers are believed by the author to have great interests in implementing VMI; however, it is currently different for non-critical item suppliers to engage in the VMI partnerships for several reasons. In addition, for major construction companies, lessons could be learned from the infrastructure industry, since cooperation between infrastructure companies and internal suppliers are maximized and advanced technologies are widely utilized in projects. The author recognizes that logistics companies showed great interests in the VMI method, since VMI could potentially help companies to obtain more business and secure long-term cooperation. Moreover, VMI to has great possibility to solve logistics and supply chain management problems in the construction sector, because it has great abilities to reduce workload to project managers, improve the demand forecasting, and etc.. As a result of the thesis, VMI is believed to be applicable in the construction industry. However, at the current stage in some circumstance, VMI is several steps further in the renovation of logistics and supply chain management in the sector. In order to facilitate the successive adaptation of VMI in the construction industry, recommendations, such as starting VMI implementations with suppliers of standard and most frequent used building materials and providing generous investments on Electronic Data Interchange and Enterprise Resource Planning systems, are proposed.

Key words: Vendor Managed Inventory (VMI), Benefits and Drawbacks of VMI, Logistics and Supply Chain Management in the Construction Industry, VMI Implementation in the Construction Industry

Contents

Preface

This research is performed in the collaboration with representatives from the Swedish construction industry and Design and Construction Project Management program at Chalmers University of Technology, Sweden. I here would like to express my sincere gratitude to my supervisor Lasse Björkman from Chalmers for his professional supports and valuable inputs, which are critical for the success of this project.

Many thanks to interviewees from the industry and relevant people involved in the study, this thesis could never been complete without their assistances.

I also appreciate my opponent – Yaning Qiao's constructive discussion and reflections on the thesis.

Göteborg October 2010

Dawei Yu

1 Introduction

1.1 The background

Even though logistics in the construction industry has been discussed frequently, still possibility of increasing the performance of logistics activities is rather high. It is nearly always profitable to study deep into the current operation system that the company has and develop its processes in accordance with logistics and lean concepts. According to Veiseth *et al.* (2003), the construction sector suffers logistics problems concerning handling the building materials and other products used during the construction period, and etc.. Thomas *et al.* (2002 cited in Veiseth *et al.*, 2003) express that one of the most common problems in construction industry is the inability of contractors to deliver materials at the right time and the right place.

Vendor managed inventory (VMI), compares with transitional logistics and supply chain management methods, is simply an approach that customers transfer massive works generated by managing inventories to suppliers. VMI offers plenteous potentials to minimize logistics activities (reduce the size of supply chains) and optimize performances of logistics activities (transportation, inventory & warehouse management, productivity & efficiency, minimize bull-whip effect, and etc.), which leads to a minimized cost of operating the entire logistic system, an increase of the quality of logistics process and an improved results of logistics performance (e.g. Waller *et al.*1999; Claassen *et al.*, 2008; Kuk, 2003). VMI has been well adapted and developed in industries like the automotive industry, the retail industry. It helps to improve the overall working efficiency of the whole supply chain which is also desired in the construction industry. However, there is hardly any research performed concerning VMI adaptations in the construction sector. Only one testing project has been found till 2009, and therefore, it is worthwhile to study in this area.

The first defendable VMI construction project was executed at Skanska Oy in Finland with the cooperation of Helsinki University of Technology (Tanskanen *et al.* 2009). This project aimed to introduce and test the adaptation of VMI methods with small items logistics in the construction industry in Finland. According to Tanskanen *et al.* (2009), small items the standard and most frequent used materials on site, for instance drills, saws, pliers, etc.. Typical logistics problems were analyzed based on interviews and workshops in order to obtain first hand information; the potential solution, which was VMI, to solve these problems were designed, proposed and executed on three construction sites with the support of a theory review. Impressive results were shown by implementing the new method. The results show great improvements in reducing wasting time in the supply chain. For instance, the rushed orders were reduced from seven per month to zero, no works were needed for receiving and storing items, and 90 percent less time was used for invoice handling.

However, there are hardly any projects done to verify the capability of VMI, explain benefits of VMI adaptations, and propose recommendations for VMI implementation in the construction industry in general. In order to motivate the industry to adapt VMI, it is

crucial to present benefits of VMI adaptations and support with practical recommendations.

1.2 Purpose

The general goal of this thesis is to study the possibility of VMI adaptations in the Swedish construction sector in general. This project firstly aims to explore the capability of implementing VMI in the construction sector by elaborating potential benefits, drawbacks, and constraints for VMI adaptations in the industry. Then, correspondent conclusions are drawn and recommendations are proposed after VMI capability in the construction industry has been verified.

1.3 Limitations

This thesis project was performed by an international master student in Sweden. And the research area was within the construction industry which is a relatively localized industry compared with computing and etc.. There were several limitations with this project that need to be mentioned.

There was limited number of interviewees available for empirical studies. Only one interviewee from different members in the supply chain of the construction industry was involved. Even though the interviewees were well experienced in their own areas, empirical findings could still be unilateral since few interviewees participated. In addition, there were limited recourses and time available for the project as this is a master thesis project.

1.4 Overview of the thesis

This thesis starts with the introduction, chapter 1, which explains the background, purposes, and limitations of this research in general. Methodology, chapter 2, provides directions of how the research was performed concerning literature review, empirical studies, and discussion. Literature review, chapter 3, supplies with basic theories for the continuous study of this project, and together with methodologies lays the foundations for empirical studies and discussions. Face-to-face interviews were carried out and relevant findings were documented in empirical studies, chapter 4, after the methodology and the literature review have been completed. Findings from empirical studies are then analyzed and discussed with the support of theories and knowledge gained from literature review in chapter 5. In chapter 6, conclusions are drawn and recommendations are proposed.

2 Methodology

Research, according to Goddard and Melville (2001), is not only collecting information for certain areas, but also is a never-ending process of exploring explanations for unanswered questions and creations generated during the process. Remenyi *et al.* (1998) stated that a correct choice of a general strategy and detailed tactics is essential for a research project. It should be done at the beginning of a project and necessary corrections should be performed during the process. Research strategy provides overall guide lines for a research, and tactics are used to direct how research should be done in a detailed level. Remenyi *et al.* (1998) explained that there are four major factors give significant influences on a research project: state research problems clearly, cost and time available for the project, and skills of project researcher(s) and relevant project participants. Five steps are suggested to follow by Remenyi *et al.* (1998) and they are:

1) Determine research questions or problems
2) Evaluate resources available for the research and perceive their constraints
3) Choose a research strategy
4) Evaluate the research strategy and perceive its constraints
5) Choose research tactics

The above mentioned five steps offer general guidance of doing this research. The research was motivated by the knowledge learned during schools at Chalmers, and the research questions were selected after studied the research area in general and with the support of constructive suggestions from the supervisor of this thesis project. Limited resources are available for this project, for instance time and costs are restricted. And constraints for this project are mainly caused by personal reasons, such as language constraints, lack of contacts of the local construction industry. Considering the limitations and the constraints, the qualitative research strategy has been selected since quantitative researches, such as surveys and workshops, were difficult to be executed. Consequently, the face-to-face interview (Section 2.2), which is widely believed as the best way to acquire data for qualitative research, was decided to be used as the research tactic for this project.

Formulating suitable research questions is a crucial step for a research project. Research questions guide the literature searching, data collection and analysis, writing-up results of a research project, and etc.. Bryman (2008) recommended four steps to select research questions and are demonstrated in figure 2.1.

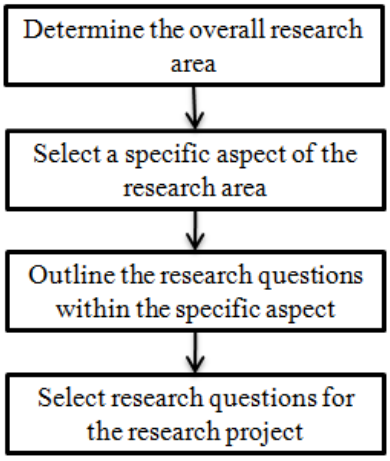

Figure 2.1 Four steps in selecting research questions (source: Bryman, 2008)

A combined research approach of deductive and inductive

The deductive approach is that ground theories are used and are reflected by observations/findings, and inductive approach is that theories are the outcomes of researches (Bryman, 2008). Hypotheses or answers to research questions are supported by theories and findings as the result of the thesis. The deductive research theory, according to Bryman (2008), is to deduce hypothesis/hypotheses from well-known theories, and hypothesis/hypotheses have to be subjected to empirical studies. The process of data collection is driven by theories and hypotheses deduced. Findings from data collected/analyzed confirm or reject the hypotheses of the project. And finally, a revision of theory is done when necessary, which in turn is a kind of inductive approach. Figure 2.2 illustrates the process of the combined research approach that is followed throughout this thesis.

Previous research works related to the project subject area, for instance characteristic problems concerning logistics and supply chain management in the construction sector in general and VMI benefit, are studied to build common background knowledge. The thesis is then started with the hypothesis of which VMI is capable in the construction sector. Interviews and data analyzing are performed with the purpose to verify the hypothesis of this project and relevant conclusions are formulated.

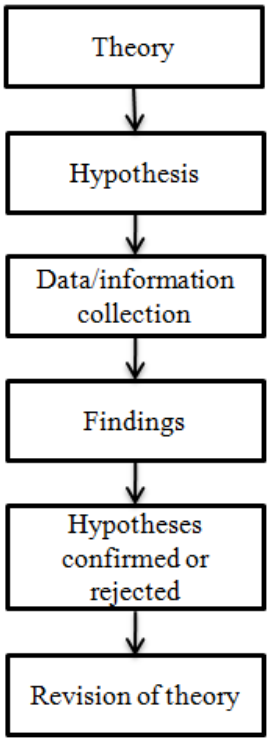

Figure 2.2 the process of deduction (source: Bryman, 2008)

2.1 Reviewing the literature

To obtain knowledge of what is already known in the area that this project is interested in, a literature review was done. The literature review affirmed the credibility of this thesis, since it is the approved knowledge of the research area from others.

Reviewing of existing literatures/theories was performed to gain the first impression of the understanding of VMI definition, its advantages and drawbacks, VMI implementation, its successive factors, and etc. in industries other than the construction industry. Fundamental understandings of characteristics of the construction industry, and logistics and supply chain managements in the construction industry were learned during the review as well. Key words were defined in relation to research areas, which are mentioned above, and were used for further literature searches. Literatures and theories were summarized and interpreted as basic knowledge to understand and analyze empirical findings which finally represent the result of this thesis. Few secondary resources were used when original information could not be achieved. Knowledge gained from previous researchers was interpreted and employed in this thesis with proper citation and listed in the references list with relevant information.

2.2 Interview

Interview is one of the most important methods for research projects, which is an essential data-collection strategy for both quantitative and qualitative research (e.g. Yin, 2004; and Bryman, 2008). Semi-structured interviews were performed as the major technique to obtain first-hand information from case studies. During this type of interviews a series of major questions were predefined before interviews as general guidance and sequences of questions could be varied according to actual condition of interviews. Open-end questions were designed and asked during interviews, which means that interviewees could offer personal opinions about certain questions and even provide their propositions (Yin, 2004).

Major interview questions were formulated in accordance with suggestions provided by Bryman (2008). Interview topics were chosen based on the research question of this thesis. Interview questions were designed to discover general conditions of the construction industry itself and logistics and supply chain management problems in the construction industry, which are the research areas of this project. Interview questions were then revised to reflect interview topics and with the support of literature reviews. In addition, open-end questions were devised to capture maximum information from interviewees without restricting their answers and reflections within confined directions.

The interviewees were selected from different parts in the supply chain from the construction industry and represent their own interests. The entire supply chain in the construction industry consists of three major groups of members: manufactures and/or suppliers, logistics companies, and the construction company. Naturally, every one of them has their own goals and interests in construction projects. Since the project's research questions cover the whole supply chain in the construction industry; thus, it is important to have at least one representative from each group.

An interviewee from an infrastructure company was chosen as well. Even though nowadays infrastructure departments operate separately from the construction industry as an individual industry, still major construction companies have their own infrastructure division and it previously categorized within the construction industry. There are similarities between these two industries. In addition, the size of the supply chain in the infrastructure industry has relatively smaller size compare with the construction industry, and should be easier to adapt new methods. Therefore, interesting findings could be found during the interview.

There were five interviews in total and they were all conducted face-to-face. Bryman (2008) states that even though telephone interview and online based interview is cheaper and quicker to be managed, still there are particular advantages of face-to-face interviews. Physical appearance of the interviewer enables possibility to notice non-verbal information from interviewees and potentially could obtain extra information (Bryman, 2008). Open-end questions were designed before interviews and follow-up questions were raised in a way to avoid any means of leading.

Information from interviews was recorded by employing a voice recorder with the permission from interviewees to use in the interviewer's research study only. To record the interview was very important for further data/information analysis. It helped to correct the natural restrictions of our memories and the intuitive glosses, allows

replicated analysis and evaluations of the interviewees' answers, and etc.. However, necessary notes were written and were used as a supplementary of the audio-recording. Note the key points of interviewee's answers were essential to propose follow-up questions when interviewee gave long answers and can not be interrupted.

Data/information was collected by inputting answers for each interview questions and was analyzed with the support of theories learned from the literature review. Findings discovered after analyzing the data generated the need of searching for new theories. Then empirical findings were compared with all theories related to research areas and were shown as the result of interviews.

3 Theoretical framework

The theoretical framework aims to create better common understanding of ground theories, such as logistics and supply chain management in the construction sector in general, and specific theories, for instance VMI, EDI, for this research, as explained in the Section 2.2.

3.1 The construction industry

Theories concerning the construction industry related to the research area are presented as the first section in the theoretical framework. This section opens up the theory section and starts with explaining fundamental logistics and supply chain management theories, then draws typical problems which further trigger the need for innovation of the logistics and supply chain management in the construction sector.

3.1.1 Supply chain management in the construction industry

The supply chain according to Christopher (1992), is "*the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumers.*"

Akintoye *et al*. (2000) explain "*construction SCM could be considered as the process of strategic management of information flow, activities, tasks and processes, involving various networks of organizations and linkages (upstream and downstream) involved in the delivery of quality construction products and services through the firms, and to the customer, in an efficient manner.*" They further state that the nature of the construction industry is a kind of investment service which the customer has great influence on the final product regarding its physical appearance and the value of logistic parameters.

Vollman *et al*. (1997 cited in Akintoye *et al*. 2000) express that construction SCM is increasingly being regarded as a series of activities with the purposes of managing and coordinating the entire supply chain from raw material suppliers to end customers. O'Brien (1999) states that SCM ensures an engineering basis with a positive attitude to design, plan, and manage construction projects coadjutant. Vrijhoef and Koskela (2000), Veiseth *et al*. (2003) and Tanskanen *et al*. (2009) explain the characteristics of the construction logistics and supply chains as:

1. It is a converging supply chain that manages all materials to the site where the property is constructed from incoming materials. And there is an excessively complex series of activities that must be performed within a limited space and time.
2. Normally one-off projects are produced in different project organizations at different locations which mean temporary supply chains are commonly found.

3. Supply chains' participants are normally involved in several projects at the same time and must have adequate logistics planning's correspondently.
4. It is a typical make-to-order supply chain with which every project actualizes a new product or prototype. Even though for a particular kind of projects the process might be similar, still there is little repetition of products.

Silva and Cardoso (1999) suggests that logistics in the construction company could be divided into supply logistics and site logistics. They further explain:

> *Supply logistics* is the function related to activities of producing building materials from raw materials to products (building materials) that could be used to construct buildings, and transporting building materials from manufacturers to construction sites. Typical activities are, for instance, supply resources specification, supply planning, delivering, and inventory control.
>
> *Site logistics* is concerning on-site activities that are related to physical resources (e.g. materials, labours, equipments, and etc.) flow planning, organizing, directing and controlling. Management of handling systems, site layout, definition of activity sequence and resolution of interference among production teams on-site are the some of the typical activities within it.

Figure 3.1 shows the boundary of logistics functions in construction companies, and illustrates how the information and material flows in the supply chain in the construction industry.

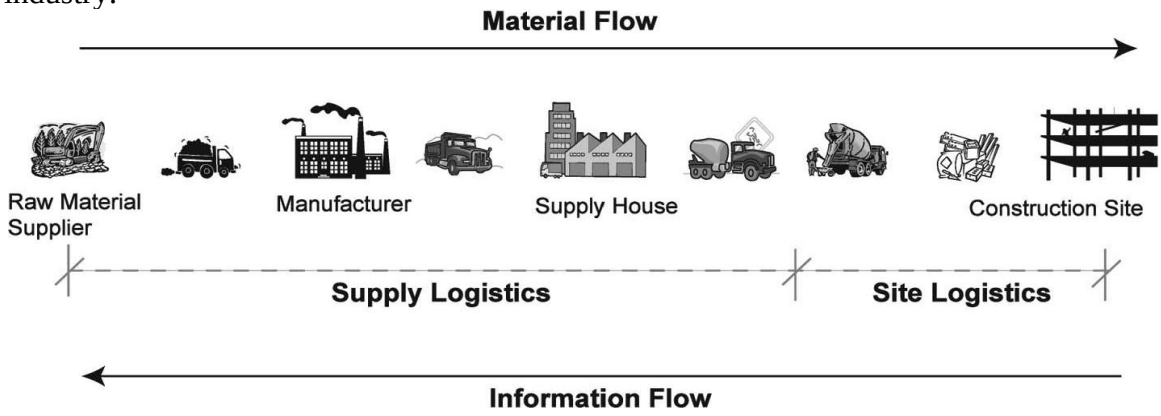

Figure 3.1 Logistics functions in construction companies (Source Jang et al., 2003)

Jang *et al.* (2003) indicate that *"the construction logistics is a multidisciplinary process which could be categorized as follows: a) material supply, storage, processing and handling; b) manpower supply; c) schedule control; d) site infrastructure and equipment location; e) site material flow management on a job site; f) management of information related to all physical and services flows."* They further argue that there always are possibilities or even necessities for additional improvements through enhanced technologies.

Vrijhoef and Koskela (2000) advocate that there are four roles in the construction SCM (figure 3.2) and these are stated as:

1. Focus on the impacts of the supply chain on site activities. The goal is to minimize expenditures and duration of site logistics activities. The method is to concentrate on creating better collaborations between suppliers and contactors so that the total efficiency of material supplies could be improved.
2. Focus on the supply chain or the supply logistics itself, with the goal of reducing cost and/or improve the efficiency, especially those relating to logistics, lead-time and inventory.
3. Focus on transferring activities from the site to earlier stages of the supply chain. The goal is to minimize or eliminate inferior conditions on site, or to achieve wider concurrencies between activities.
4. Focus on the entire supply chain which the site logistics is included. It is aim to integrate managements of the whole supply chain, improve the total efficiency of the supply chain and the site production.

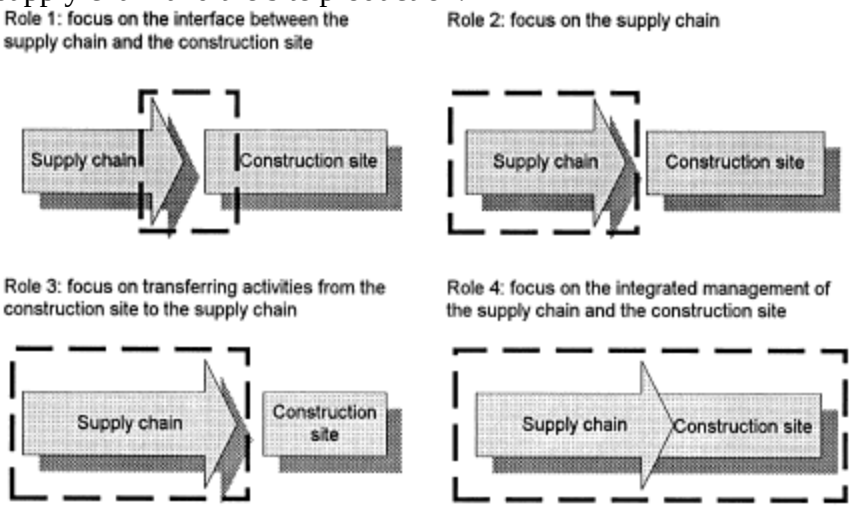

Figure 3.2 the four roles of supply chain management in construction (Source: Vrijhoef and Koskela 2000)

3.1.2 Logistics in construction

Vrijhoef and Koskela (1999) indicate that myopic controls of supply chains and logistics activities are widely found in the construction sector and cause wastes and problems. The general methodology, theory and practice of SCM enable better understanding and resolution of basic problems in construction supply chains, and provide recommendations for the future development of the construction supply chain. However, since the uniqueness of construction supply chains exist, most of practical SCM solutions have to be developed to match the construction practice.

Problems in construction supply chains are largely characterized by interdependency. Myopic control of the construction supply chain, for instance decisions that are made with lack of information or understanding, combined with traditional trading and non-cooperative relationships, reinforces the problems, and complicates their resolution (Vrijhoef and Koskela, 1999).

The first thing suggested to do is to assess supply chains to discover the nature and causality of the problems, which basically means to make wastes and problems visible and tangible, and identifying and detecting the root causes so that potential solutions could be identified. Secondly, after assessing the supply chain, the SCM methodology suggests redesign (reconfiguring the supply chain's structure), control (coordinating the supply chain according to the new configuration) and continuous improvement. In general, actors involved in the construction supply chains should have a common goal for development and adapt the same approach to specific issues to ensure the integrated improvement. Moreover, Vrijhoef and Koskela (1999) summarize and illustrate typical samples of typical practices in the construction industry (table 3.1).

The SCM methodology is firstly properly deployed on a lower scale, addressing partial supply chain problems, involving a limited number of supply chain participants. And SCM is addressed for further improvement in an increasing number of areas of application continuously over time. In addition, the partial problem areas in construction supply chains are closely interrelated. For instance, it is often difficult to improve the dependability of the deliveries of a supply chain without identifying the whole supply chain. Therefore, SCM improvement should be targeted to reduce the total costs and duration, which could be understand as improving the performance of the entire construction supply chain.

Development issues	Description of the development	Actual construction practice
Order information transparency	The issue is how to manage the order information propagation to improve the supply chain.	It is not rare to find that the placing of a subcontract or material order is delayed due to price negotiations. As a result, the order information propagation is effectively halted.
Reduction of variability	The issue is how to reduce variability and how to make the supply chain robust when facing uncertainty.	Changes to orders, originating from the sphere of the client, the design team or the main contractor, are quite usual.
Synchronization of material flows	The issue is how to synchronize the availability of materials for assembly.	It is not uncommon to see that materials are produced in an order suitable for the supplying factory, and delivered to the site in a mode minimizing the transportation costs. Thus, other considerations than the needs of assembly dominate.
Management of critical resources	The issue is how to identify critical resources, lay out a critical path network and put the effort on reducing the workload of critical resources.	In the traditional design-bid-build procurement in construction, where the parties are selected based on price, it often is impossible or difficult to objectively identify critical resources of the supply chain in advance.
Configuration of the supply chain	The issue is how to evaluate and then change the chain.	This kind of continuous and long-term improvement of the supply chain is out of question, because for each project, a new supply chain is configured.

Table 3.1 Development Issues of SCM in the construction sector (source: Vrijhoef and Koskela 1999)

3.1.3 Problems in the construction industry

Vrijhoef and Koskela (1999) identify three major causes of SCM problems in the construction sector and these are summarized as:

1. Plenty of waste and problems are always found in the construction supply chain, since most companies or departments in the same company appear to be managing just their own parts and securing their own businesses.
2. Most of the waste and problems are caused by activities in another stage of the construction supply chain other than where they are found. The root causes of the waste and problems were rarely found in the activity where they were encountered, but rather in a previous activity executed by a prior actor and often operating on a higher organizational level.
3. Waste and problems are largely caused by myopic control of the construction supply chain. In most cases, actors are encouraged to optimize their own part of the chain, not taking into account other activities and actors in the supply chain.

Dainty *et al*. (2001) explain that the construction sector faces wide fluctuating demand cycles, project-specific product demands, uncertain production conditions, and there are also evidences of a combined diverse range of professional skills within geographically dispersed short-term project circumstances. They also state that, in UK, the increased fragmentation of the production process has further exacerbated the diversity and unstable condition in the construction sector.

Thomas *et al*. (2002) illustrate that one of the most common problems in construction is the inability of the contractor to deliver materials at the right time and the right location, which could be the result of deficient storage planning together with lack of routines for the receiving of materials (Veiseth *et al*., 2003). Thomas *et al*. (2002) also define problems in the flow of equipment and information are critical to improve the productivity in the construction sector. They also indicate that potential improvement areas are widely found in both the planning of how to organize the construction site and of the logistic of the building itself.

Veiseth *et al*. (2003) indicate that, in the construction industry, there is an identified tendency that participants in chains only focus on planning their own field instead of taking others' planning into consideration. They further explain that, since construction projects are one-off kinds and thus actors in the construction sector to seek for the maximum profit out of each project, which is in contrast to the objective of SCM – to create the most value not solely for any one company but for the whole supply chain network (Akintoye *et al*., 2000).

Purchase routines, in which normally huge numbers of rush orders are found, are identified as an important field that needs to be considered when exploring the cause of low productivity in the construction sector (Veiseth *et al*., 2003), since it typically causes extra costs and delays for projects.

Moreover, Dainty *et al*. (2001) indicate the lack of trust and negative attitudes towards many key successful factors of SCM, which indicate that the construction industry is still far away from being able to integrate systems and processes for project performance improvement. Akintoye *et al*. (2000) also define that the lack of trust among supply chain

actors, the lack of senior management commitment, the lack of appropriate support structures, and commonly found ignorance of SCM philosophy are the major obstacles for the construction industry to emulate other industries.

3.1.4 Need for innovation

Saad *et al.* (2002) suggest that, even though innovation in the supply chain is a complex process as it typically involves many different functions, actors and variables, still there is a need for the innovation of the construction supply chain.

Saad *et al.* (2002) express that SCM can assist the construction sector to overcome its inherent fragmentation and adversarial culture in the supply chains, improve relationships among actors and enable better integration in its processes; and therefore is seen as a multi-factor innovation. Continuous learning, share of SCM knowledge and key partners' commitments are identified as evidences of effective implementation of SCM.

However, Saad *et al.* (2002) also notice several inconsistencies such as:

1. The construction sector has only recently started moving to more collaborative relationships and integrated processes with the emergence of partnering in the industry. Even in this case, partnering is mainly adapted between clients, consultants and main contractors, and rarely found downstream in the supply chains from main contractors.
2. Even though actors admit the importance of long-term and close relationships in the application of SCM, still contradictions are observed as the unwillingness to, for instances, exchange information openly and share learning and etc.
3. Although learning, which mismatch the competencies and the cultural changes needed for the complex, multi-factor and dynamic innovation of construction supply chains, is commonly recognized as essential for by practitioners.

Saad *et al.* (2002) also identify the influencing role of clients and their advisors in leading and championing change in construction.

Egan (1998, 2002) argues for the importance of innovation within the construction industry, and proposed that continuous service, product improvement, and company profitability can only be achieved through innovation. Khalfan and McDermott (2006) indicate that even though there is a growing realization of innovation among actors in construction supply chains, still the establishment of procurement systems and procedures to promote innovation within construction organizations is at a developing stage. They advocate that the persistence positive manner of sharing knowledge and experiences among project partners is critical to maintain the momentum gains of the innovation.

3.2 Vendor managed inventory

VMI is an effective method to solve logistics problems and could be a future direction of the construction supply chain management's innovation mentioned in the earlier section.

3.2.1 VMI in brief

Blatherwick, (1998 cited in Claassen *et al.*, 2008), and Cachon and Fisher, (1997 cited in Claassen *et al.*, 2008) explain that VMI originated in the early 1980s with mass retailers demanding vendors to take up the responsibility for inventory replenishment based on sales figures made available by the retailer. Harrison and Van Hoek (2008) define VMI as an approach to inventory and order fulfilment whereby the supplier, not the customer, is responsible for managing and replenishing inventory.

The suppliers, according to Kuk (2003), with VMI implementation, take over the power and the responsibility of planning and requiring orders for the customers according to the actual condition of inventories. Moreover, suppliers could stabilize or even optimize their production and transportation system (Claassen *et al.*, 2008) since the control key of resupply decisions is relinquished from the customer (Waller *et al.*1999). Customers, in VMI system, are relieved from managing to just provide reliably sufficient inventory information (Claassen *et al.*, 2008), full inventory access and the confirmation of order initiated by suppliers.

VMI is a partnering initiative (Waller *et al.*, 1999). Therefore, utilization of partners' competences and better resource usages are achieved, which enable win-win situations for participants involved.

3.2.2 How to implement VMI

VMI executes in a circumstance where partnership is built and agreements are made before actual implementation. Suppliers are given the right to access customers' inventory at any time and the power of making decision of replenishing inventories is awarded as well. In order to maintain sufficient inventory level, comprehensive communication and information sharing system, such as *electronic data interchange (EDI)*, has to be established among participants. With EDI, all participants' production plans and any other logistics related information (materials usage, inventory ordering and products transferring status, and etc.) are available to others. In addition, with the support of suitable production/resource planning system, such as *enterprise resource planning (ERP)*, all participants within a VMI relationship benefit from an optimized production and efficient transportation. There are two suggested models for VMI implementation as shown in figure 3.3. Model 1 illustrates VMI operating method with manufacturers that has supply and transportation functions and model 2 shows VMI implementation with a VMI company (e.g. Claassen *et al.*, 2008; Harrison and Van Hoek, 2008; Waller *et al.*, 1999).

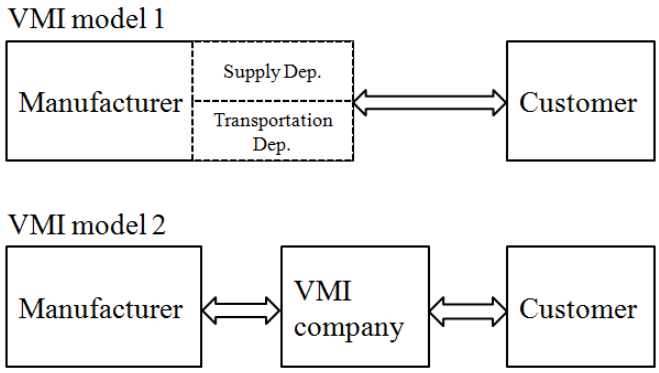

Figure 3.3 Models for VMI implementation

Preparation for implementing VMI

Kuk (2004) indicates that VMI initiatives are information intensive and require database linkages among supply chain partners to facilitate information flow. Claassen *et al.* (2008) state that the extensive information sharing is one of the influencing factors for VMI to be successful, and moreover, they argue that relationships based on trust and commitment are the dominant factors to obtain a successful VMI implementation. Activities in the phase can be divided as following (figure 3.4):

1. All participants clarify expectations and their current relevant information. At the initial stage, customers and suppliers should communicate what they expect out from the VMI partnerships. Real-time hardware information, such as current warehouse condition, and software information, such as information sharing system, should be identified and further relevant requirements should be discussed at the same time. Moreover, plan for VMI implementation should be decided so that each participant's responsibility is aware.
2. The customer must be willing to share first-hand real-time exact information. The appropriate inventory management from supplier requires precise information of customer's sales and inventory information. Therefore, the customer must trust the supplier and provide reliable information when necessary.
3. Suppliers must guarantee reliable transmission, receipt, and use of information from customer side. Naturally, the customer would be ensured that information that is presented to suppliers is properly utilized. Further, suppliers must proof their ability in realizing agreed responsibilities.
4. Substantial inspection of information and communication system has to be done before actual VMI implementation. The system is the only channel that should be used in VMI relationship to communicate relevant information. Therefore, its efficiency is a critical factor and has to be secured.
5. Expect implementation to be a process not a project. Nothing is perfect, adjustments or improvements must be done all along as the VMI partnership continues. And thus, participants need to be tolerant in financial and time consumption at initial.

VMI implementation

Applying VMI means that, the supplier, or the vendor, on the basis of received stock balance and demand information, manages the customer stock and continuously plans new replenishment orders, effectively placing purchasing orders in his customer's enterprise resource planning (ERP) system (Jonsson, 2008). Further, Jonsson (2008) and Harrison and Van Hoek (2008), express their emphases on the importance of accessibility to the real-time demand at the customer or information sharing between supplier and customer. Therefore, Jonsson (2008) and Harrison and van Hoek (2008), recommend the electronic data interchange (EDI) system, which is believed to be most widely used technology for broadcasting demand data from the customer (Harrison and Van Hoek, 2008), to VMI partners to be use as the best system for information sharing. Procedures in this stage could be summarized as:

6. The actual implementation of VMI should be started by the supplier's first inspection of the customer's warehouse and inventory, and take over the managing issues if the inventories already exist.
7. The supplier executes the continuous inspection of the customer's inventory with the respects of: 1) the current level of inventories; 2) with the support of the customer's enterprise resource planning (ERP) system, estimate customer's inventory consumption and demand for the next period; 3) evaluate the forecast together with customer by EDI system; 4) necessary adjustment based on the revised demand prediction and supported by the supplier's ERP system.
8. Ordering process: 1) orders are initiated when the agreed level of supply, like the economic order quantity, is achieved; 2) orders are sent through the EDI system directly to customer when they are generated; 3) relative person from the customer' organization review the order, confirm and submit orders to suppliers; 4) orders are received by supplier.
9. Supply activities: 1) input ordering and supply data to the supplier's ERP system; 2) delivers the products from supplier's warehouse to customer and relevant information, such as condition of products, is registered; meanwhile, plan and execute the production; 3) new products replenished into supplier's warehouse.
10. Consumption of products: 1) products are received and their ownerships are transferred to the customer once they are being used; 2) use of products; 3) un-used standardized products are returned to supplier if agreements are made in advance.
11. Continuous cycle from step seven to step ten with the same project, or start from first step for new projects.

Reviewing the VMI implementation

Kamara *et al.* (2002) explain that since the construction industry operates within a dynamic and changing environment, the need for knowledge management is originated and accelerated by the need for innovation, improved business performance and client satisfaction. Thus, knowledge management is essential for gaining competitiveness advantages in the construction sector and should be applied as well when VMI is actually implemented. The following activities are included:

12. Problems occurred concerning the VMI are registered during the project and discussed at the end of project for future development.

13. Document valuable information of VMI implementation and prepare for potentially future use.

It is critical to ensure the transparent and effective information sharing among participants within VMI relationships. In addition, an integrated planning system enables the possibility to improve the overall efficiency of the supply chain (e.g. Holmstrom, 1998; Claassen *et al.*, 2008; Jonsson, 2008; Harrison and Van Hoek, 2008). Therefore, EDI and ERP are introduced in the section 3.3 and 3.4.

3.2.3 VMI benefits

VMI in general contributes to reduce inventory cost and improvements in customer service level. The warehouse efficiency is improved as the suppliers' expert knowledge of product is used, in addition to this, with the proper cooperation between customers and suppliers inventory level is lowered without any compromising of product availability (Waller *et al.* 1999).

All participants involved benefit from reduction of transportation costs, which is achieved by increasing of truck fulfil rate and more efficient route planning. Moreover, VMI partnership allows the suppliers to balance or fulfil specific customer's emergent requiring of their products by transferring between several customers. Customers benefit from similar situation as they have the possibility to return products to suppliers that could be potentially ordered by others. Customers are also relieved from the dilemma of different measures of inventory management or even of the whole logistic system; for instances, balance between safety stock level and inventory carry cost, ordering frequency and transportation costs, and etc. (Waller *et al.*, 1999). VMI provides improvements in efficiency, responsiveness and decreasing inventory levels, which in turn transferred to customer as lower prices (e.g. Holmstrom, 1998; Waller *et al.*, 1999). Holmstrom (1998) also indicates that growing and more cost efficient sales are achieved as a successful relationship is built.

After several studies, Kuk (2004) describes VMI as a tool used to improve customer services and reduce inventory cost. VMI in general can result in reduced incidences of stock-out situations and hence an increase in the levels of customer services, and cost reduction due to an increase in inventory turns and decrease in the levels of safety stock (Davis, 1993). Kuk (2004) states that with proper VMI adaptation, cost reductions in the supply chain are realized since its ability to optimize the production and planning capacity, high levels of participants involvement, and logistics integration which mitigate situations of late and defective supplies.

Lee *et al.* (1997) states that, the bullwhip effect refers to the phenomenon that demands, which confirm to sales to the buyer, are amplified upstream in the supply chain to the supplier, and therefore distortions of demands are generated in a large scale. Thus, over-ordering over-production and high inventory level are found in the whole supply chain. Further, they argue that, information which orders are generated upon should be best transferred downstream to dampen the bullwhip effect. Moreover, Disney and Towill (2003) argue that VMI can contribute to positive impacts on bullwhip effects and it can

provide great benefits to the suppliers. They explain that with VMI one of the fundamental characteristic and problem in the traditional supply chain, which is that all participants must estimate their orders to enable a supply chain echelon to satisfy its customers' "demands", is eliminated. Holmstrom (1998) explains with VMI partnership suppliers take responsibility of managing and replenishing customers' inventory, so that double buffering against supply disruptions could be eliminated and accuracy of planning supply requests from producers could be improved.

3.2.4 Constraints and drawbacks of implementing VMI

VMI is regarded as the integration of the supply chain. Its implementation requires collaborations of all participants in supply chains for certain projects. Every member in the chain has significant influences on the implementation of VMI. Thus, there are several constraints with VMI implementation (e.g. Claassen *et al.*, 2008; Harrison and van Hoek, 2008; Waller *et al.*, 1999):

- Top management commitments could be understood as participant's vulnerability of adapting VMI in the chain. Without top management commitments, no investments could be realized and could result in no resources available to initiate VMI implementation potentially.
- Relationships among VMI partners heavily influence the cooperation and trusts among VMI partners. And as a result, transparent and effective communication, which is critical for VMI adaptation, could not be actualized if relationships could not achieve certain level.
- The quality and the efficiency of information sharing and communication is the key in the VMI implementation, since all works have to be executed with the support of sufficient and adequate information. Any failure in information sharing will result in unrealistic forecast of demands of materials and the VMI adaptation will be lead to a failure.
- The integrated planning system is essential for participants in supply chains to avoid isolating themselves from others and having conflicting individual goals. The overall efficiency of supply chains could not be maximized, if members can not obtain a general view of the production for the entire supply chain.
- A successive VMI adaptation requires adequate ability of suppliers in the supply chain. The inability of suppliers regarding receiving and interpreting information from others, forecasting materials demands, producing and delivering materials according to customers' requirements, and etc., seriously affects the implementation of VMI and could collapse VMI adaptations totally.
- Lack of standard procedures and formats is another counteracting factor during the adaptation of VMI. Without standard procedures and formats, it is nearly impossible for participants in supply chains to transfer knowledge and experiences learned from one VMI implementation to another. It also generates difficulties in predicting activities when VMI is adapted.
- Since VMI triggers the changes of original structures of organizations, and potentially requires innovations of information and planning systems. Thus, high investments demanded could obstruct positive intentions towards VMI adaptation.

Besides the constraints mentioned above, there are certain drawbacks when implementing VMI in the supply chain. For instance (e.g. QuickMBA, 200? and 12manage, 200?):

- Customers may feel that they lose the control. Power and the responsibility of deciding what materials are needed, how many and when are needed, and etc. shifts to the suppliers' side in the VMI partnership.
- VMI partners, especially suppliers, face problems like taking the risks of inventories from customers, such as risks of disruption in the production and etc..
- Extensive data is processed among VMI partners. VMI implementation requires sufficient and real-time information, which means that massive data has to be produced and shared.
- Benefits are not divided equally among VMI partners. It seems that there are more direct benefits obtained by suppliers, meanwhile, customers have to give up some of their power and traditional control of the supply chain.
- Potentials of loss of jobs enable extra resistances from employees of supply chains' participants. Since proper adaptation of VMI results in a minimized sized and number of activities of supply chains, and these result in loss of jobs for some employees.

3.3 Electronic data interchange (EDI)

An effective and transparent information sharing is essential for the success of VMI adaptations. Even though researchers, such as Waller *et al.* (1999), indicate that EDI is not compulsory for VMI implementation, still it provides solid support for the information sharing within VMI partners.

3.3.1 EDI in brief

The concept of EDI that is used through this work is, as Holland and Lockett (1992) quoted the information technology that is used to exchange information among organizations without the limitation of their boundaries. Jonsson (2008) explains further about the EDI, that data are transferred from one computer system to another in a predefined and standardized format and in such a way that the receiving system can interpret and process the information. Hence, the EDI is one form of inter-organizational information system, which means an automated information system shared by two or more companies (Cash and Konsynki, 1985 cited in Barua and Lee 1997), with specific standards.

According to Lambert *et al.* (1998), in order to obtain the proper EDI function, two fundamental factors require attentions. Firstly, traditional fax transmissions do not qualify since EDI is based on a computer – computer system. Secondly, communication standards in computer language or the capability of computer language is crucial.

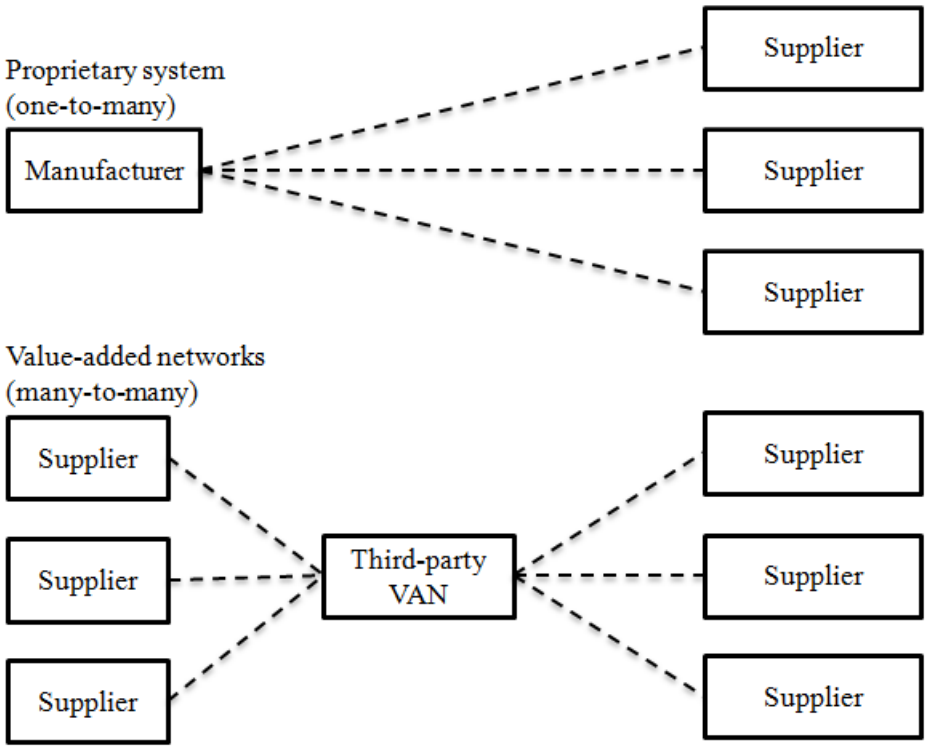

Figure 3.4 Typical EDI configurations (source: Lambert et al., 1998)

However, Lambert *et al.* (1998) suggest a popular EDI system, *value-added networks* (VANs), has the potential to ease the requirements above. With VANs, participants in a

specific supply chain are connected by a third party, which function as a data interpreting organization; value is added by third party in case of when participants have failed or are not capable to communicate with respect standards. Therefore, partners in the supply chain are relieved from original rigorous demands for a proper EDI to function. The sample of VANs is illustrated in the figure 3.4.

3.3.2 Benefits of EDI

After studied relevant literatures, Teo *et al.* (1995) indicate that with the support of EDI, several improvements of entire supply chain performance could be achieved. They further explain this in detail:

> *"Many potential benefits can accrue from the proper use of EDI. These include improved customer service, decreased manufacturing costs, improved data control, and reduced clerical errors that result in improved productivity, enhanced competitive advantage, reduced financial exposure, and better cash management."*

Holland *et al.* (1992) argue that EDI enables quicker and more accurate orders and invoices exchanges. Further EDI assists participants to plan more effectively, since its ability to exchange relevant, timely and accurate information. They also indicate that using EDI could help participants to lock their competitors out from their existing business, as EDI has a great efficiency in information sharing which eliminates the time for competitors to react correspondingly. Konsynski and McFarlan (1990, as cited in Holland *et al.*, 1992) explain that EDI links eliminate constraints concerning the volume and the speed of information flows among parties involved which enables vertical information integration in the supply chain. EDI could reduce the inventory levels since it improves the quality and timeliness of information so that orders can be placed more frequently and in smaller quantities. They further express that incorporated with distribution organizations, efficiency of transportation could be improved. With the support of EDI, information quality, for instance, demand distortion, is improved by closer distance among various organizations.

Lambert *et al*. (1998) explain that one of the most significant benefits of proper EDI adaptation and integration is that, it reduces the need for clerical work in the information flow. In addition EDI minimizes the paperwork, increasing accuracy and speed, and etc.. Carbone (1992, as cited in Lambert *et al*., 1998) states that, EDI could lead to a reduction of 80 percent of expenditure of purchasing process.

Weber and Kantaneni (2002) indicate that EDI minimizes the cost to correct information error since it only requires one time data input instead of multiple computer data entries in the traditional logistics and supply chain. EDI also provides the possibility to reduce investment in inventory and improve the responsiveness to market because it establishes a platform for all participants to share and access others real-time condition and requirement of correspondent supplies.

3.3.3 Drawbacks

EDI requires commitments from senior management in organizations to be successful. Adaptation of EDI means to change or impact the organizational structure, procedures and management, which could further lead to change in the organizational culture (Scala and McGrath, 1993). Since there is a lack of common standard in EDI (Scala and McGrath, 1993), EDI systems are thus generally incompatible with each other (Harrison and Van Hoek, 2008) which naturally results in multiple initial investments if certain participants are involved in several logistics systems or supply chains with different EDI systems.

Moreover, Bara and Lee (1997) argues that, for smaller suppliers in the supply chain, the EDI system might be an "unfortunate" strategic necessity; meanwhile, larger suppliers would be more in favor of EDI system since it is a "beneficial" strategic necessity.

Weber and Kantaneni (2002) state that EDI adaptation requires significant cost barriers which means that EDI benefits are only achievable when high, upfront investment is made. Moreover, the willingness for sharing data and trust among participants are influencing as well.

In summary, the EDI system provides significant improvement in the efficiency and accuracy of information sharing which is critical for VMI implementation. Even though, it is not compulsory, since the traditional information technology still could afford the massive workload with information sharing, still the EDI contributes more and it is recommended among the VMI partners (e.g. Holmstrom, 1998; and Waller *et al.*, 1999).

3.4 Enterprise resource planning (ERP)

While EDI eases VMI implementation with creating effective communication channels among partners, ERP is believed to facilitate participants in the VMI relationship with adequate ability to receive and interpret information from others into their own organizations.

3.4.1 ERP definition

ERP systems, according to Mabert *et al.* (2003), are enterprise-wide on-line interactive systems that support cross-functional operations based on a common database. Shehad *et al.* (2004) further explain that ERP is a business management system that comprises integrated sets of comprehensive software to manage and integrate all the business functions within an organization.

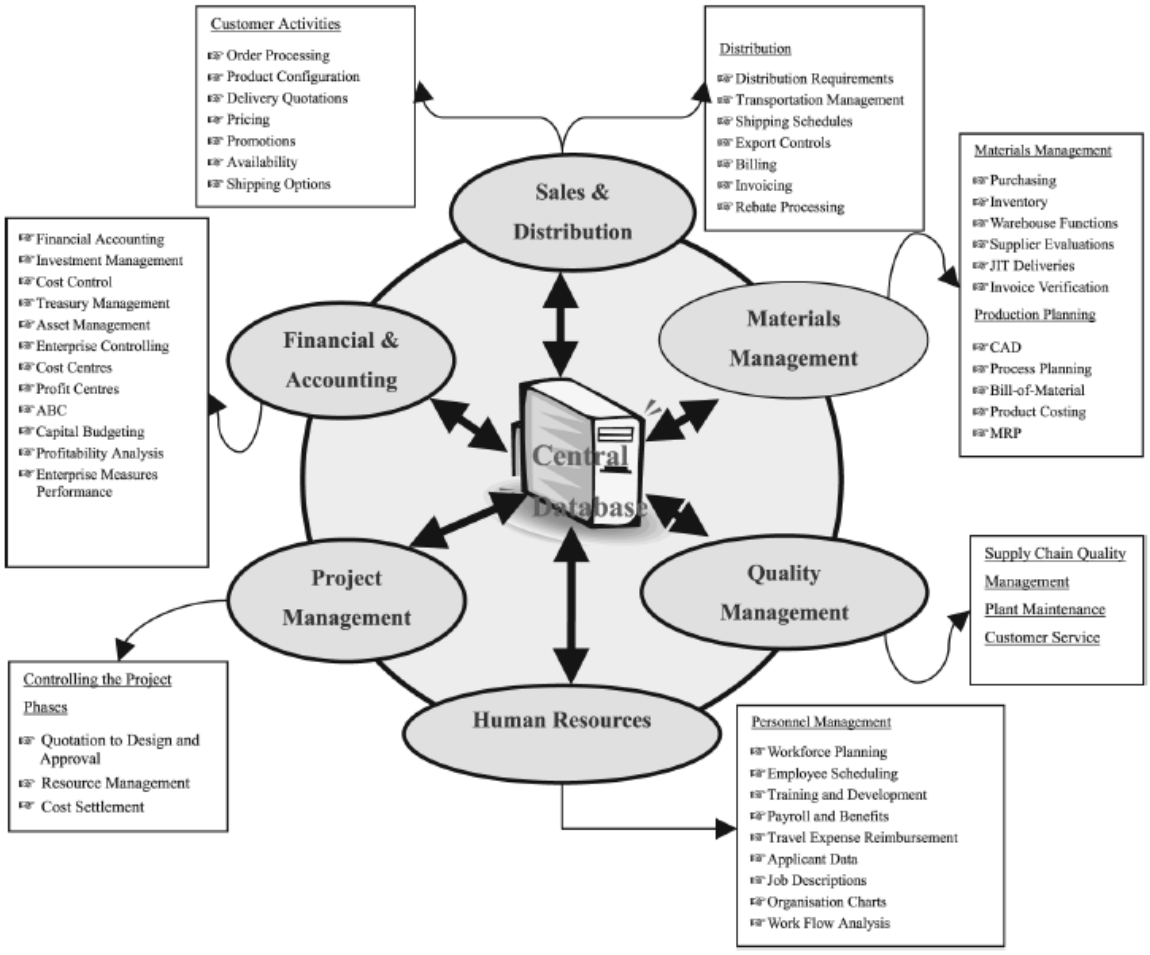

Figure 3.5 ERP system modules (Source: Shehad et al., 2004)

3.4.2 Benefits of ERP

As shown in figure 3.5, typical ERP system covers all functions, such as Sales & Distribution, Financial & Accounting, Materials Management, Project Management, and Quality Management within one enterprise. The central/common database is the key element in an ERP system, since it is the place that all information is received, transferred and gathered so that the "cooperation" is realized. Therefore, Shehab *et al.* (2004) state that suitable ERP systems provide a tightly integrated solution to an organization's information system needs.

The figure 3.6 shows the basic structure of the ERP system in a transnational enterprise and indicates that ERP system builds on the cross-department cooperation. Holland and Light (1999) state that the purpose of the system is to improve customer links to stock and production information. They further explain that ERP system ease the rationalization of manufacturing and administrative overheads.

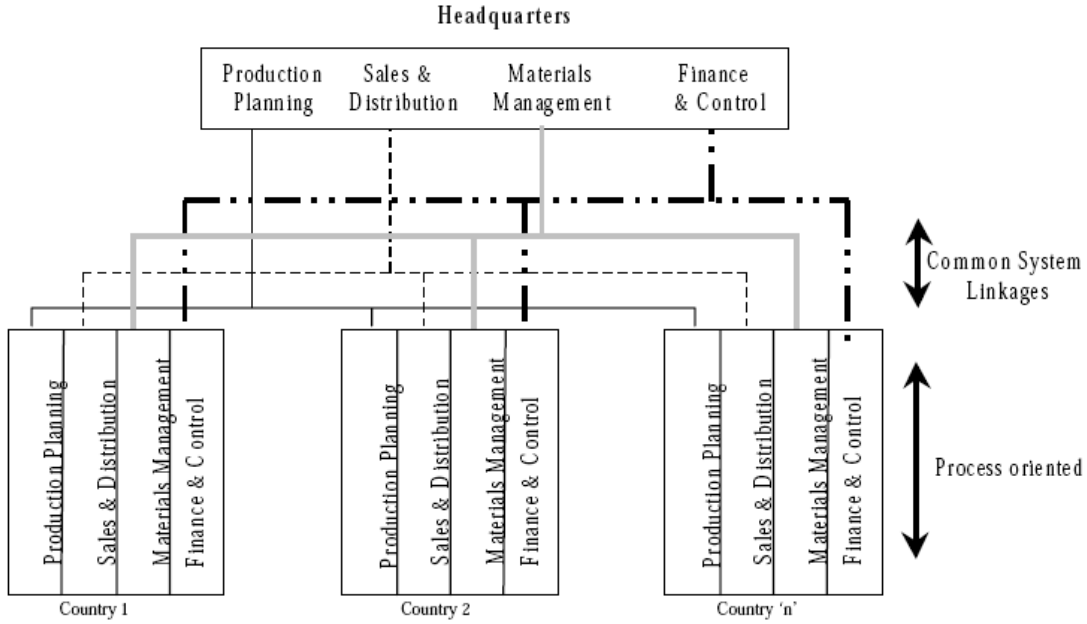

Figure 3.6 the sample structure of ERP system (Source: Holland and Light, 1999)

Umble *et al.* (2003) believe that there are two major benefits that ERP system could offer: 1) organization's functions and departments will be encompassed with a unified enterprise's business view, which facilitate companies to improve communication and responsiveness to all stakeholders; 2) all business transactions are entered, recorded, processed, monitored, and reported in enterprise/common database. These major benefits potentially result in, as Chen (2001) states, reductions in working capital, abundant and accurate information from and to customers, ability and possibility to integrate enterprise with suppliers and customers, and etc. Gupta (2000) reports that proper implementation of ERP reduce inventories from 15 to 35 per cent in the manufacturing sector.

3.4.3 ERP drawbacks

Since ERP is a web-based software system which covers all functional units within an enterprise, there are several major drawbacks (Mabert *et al.*, 2003; Shehab *et al.*, 2004; Umble *et al.*, 2003):

- A huge database to store all information of an enterprise includes administrative, business and production related information. And all this information has to be up-to-date at all times.
- Pre-defined business management software packages and tools are used, which means companies have to adjust their existing units accordingly.
- It is a long process to merge ERP into enterprise's daily operations due to the necessary changes of existing organizational units.
- Employees have to be trained since adequate ability is required to use pre-defined software properly.
- Performance measurements are required to facilitate the utilization of ERP. Continuous necessary adjustment of the ERP or organizational units and/or further training to the employees are carried out after the first-time ERP implementation and possibly developed along with the enterprise's expansion.
- It requires long duration from the investigation and the implementation until being beneficial, because the ERP system is complex.

In summary, ERP systems first require top management commitment to implement successfully. It also requires adequate and continuous training of employees, professional project management, close cooperation across organizational boundaries within an enterprise, and etc.. Thus, the ERP system is very complex. However, it is essential for both suppliers and customers to obtain a successful implementation of VMI, since VMI partners' abilities to handle information from others and utilize it in their own production is critical (e.g. Claassen *et al.*, 2008; Harrison and van Hoek, 2008).

3.5 Short introduction of the Kraljic purchasing model

Relationships between the customer and the supplier have significant influences on opinions of whether VMI should be implemented. In 1983, Peter Kraljic has firstly proposed a model to describe these relationships and this model is widely recognized as the Kraljic purchasing model.

3.5.1 The Kraljic purchasing model

The Kraljic purchasing model was created and first presented by Peter Kraljic in 1983 in the Harvard Business Review. Even though decades have past, still it is widely used in both business and academic circumstances. The Kraljic (1983) develop his purchasing model with the purpose to provide a simple but effective framework for companies so that suitable strategies for purchasing items are easy to identify.

Kraljic (1983) design his model based on two primary factors: 1) the strategic importance of purchasing items in relation to their profitability profiles, value added profiles, etc., for instance, if products have high value or profit impacts to both suppliers and customers; 2) the complexity of the supply market, for instance, monopoly and/or oligopoly conditions of items, production technology of items and/or their substitution, etc., which further determine to what extent materials supply are affected by risks of availabilities of products. According to 12manage (199?) and Mind Tools (1995?), profit impacts mean that value added by production lines to certain products and/or product prices in relation to total costs of raw materials and impacts of raw materials costs on the profitability of products; meanwhile, supply risks describe difficulties of buying products, which are influenced by natural disasters, delivery logistics and etc.. Consequently, four different purchasing strategies are developed (Kraljic, 1983) and the model is simplified and summarized as following (e.g. 12manage, 199?; Jonsson, 2008; Mind Tools, 1995?) (Figure 3.7):

- Non-critical items – materials which are commodities with relatively short-term time horizon (12 months or less). The competitive price is one of the most important purchasing criteria. Items within this area typically have low profit impacts and supply risks.
- Bottleneck items – items which are specified materials with variable time horizons. Cost management and reliable short-term sourcing are the most important criteria within this pattern. Materials within this range normally have low profit impacts but high supply risks.
- Leverage items – items those are a mix of commodities and specified materials with relatively longer time horizons (typically 12 to 24 months). Items' costs in relations to their prices and materials flow management are essential in this area. This type of materials normally has high profit impacts but low supply risks.
- Strategic items – items those are scarce and/or high-value materials with long time horizons (up to ten years). Ensuring long-term availability is critical. And this type of items has high profit impacts and supply risks.

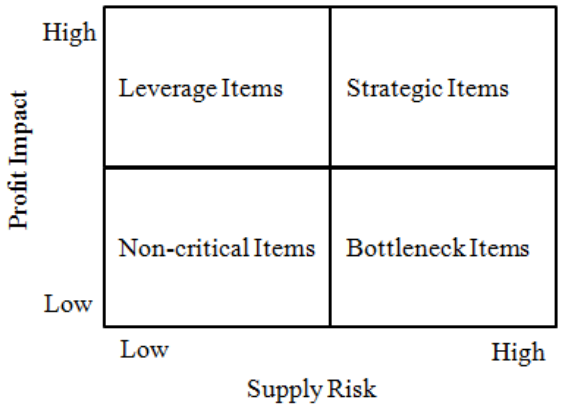

Figure 3.7 Kraljic purchasing model (source: e.g. 12manage, 199?; Jonsson, 2008)

4 Empirical findings

4.1 The case of company A

Company A is an innovative and personal construction and civil engineering company with the strength of a large group combined with a local company's ability to create flexible solutions. There are approximately 13,000 employees at the company and the turnover is more than 35 billion SEK. The group covers three business areas *Construction, Civil Engineering and Industry*. The company is presented at more than 100 locations in Sweden, and has its own market places in Norway and Finland as well.

The interview is carried out at the division west of the company which is located at Göteborg Sweden, and the interviewee is from the purchasing department of the company. The interviewee has been working in the companies for more than 8 years, and previously, he had worked within purchasing in other major Swedish companies for several years as well. Therefore, the knowledge gained from the interview is more purchasing oriented.

4.1.1 The warehouse system

According to the interviewee, there is no traditional warehouse for the company; however, they do outsource the warehouse to their suppliers. This means that the company's suppliers take care of one central warehouse and normally is paid by the company. In this case, the company normally just has to identify the most frequent ordered materials and make formal frame agreements with suppliers. In addition, the company and its suppliers discuss the production/manufacturing process of the most frequently ordered materials together so that better planning will be produced.

The company and its suppliers cooperate with a logistic company to coordinate the materials on site. The logistic company unloads the packages and delivers building materials during the night to a specific place with certain amount according to detailed information provided by its customer. "The logistic company is definitely more professional" confirmed by the interviewee A; nevertheless, he also mentioned that there are still many companies that believe that they can manage the logistic works properly by themselves.

4.1.2 The information system and communication

The EDI system is found in the company and used as a purchasing system – the "call-off" system. All information about building materials such as, material itself, its supplier, its shipment and etc. are presented in the "call-off" system; therefore, the company has sufficient information to order and purchase. Since this system is an online based system, ordering and/or purchasing information is sent to relevant supplier directly, and thus, production and supply activities are executed immediately.

The interviewee stated that, for approximately 95 percent, he is satisfied with the information sharing, but this still could be done better. For the company, there is a weak

point of transferring material requirements to suppliers, because there are simply too much information that needs to be exchanged when the information is transferring and/or sharing in the supply chain, it is not only just what kind of materials are needed at which time. The interviewee also mentioned that "*as the whole industry is very bad at planning and giving back the information that we have access to when it comes to what kind of materials that we need on that day*."

The interviewee confirmed that massive savings are realized by using this system. For instance, fewer employees are needed to process ordering and purchasing compare with traditional paper/fax purchasing system; quick responses for ordering and/or purchasing activities; time-saving in processing ordering and purchasing; and consequently cost-savings are achieved.

Besides the benefits mentioned above, the interviewee also stated that it is very expensive and time consuming to implement the "call-off" system. And not all the company's suppliers either realize the benefits or are willing to investigate on it. Thus, there is a certain percentage of the company's suppliers still using the traditional way of purchasing. The company is continuously introducing this new system to its suppliers by showing them the benefits and offering incentives when suppliers are implementing the "call-off" system.

4.1.3 The lead-time

As a consequence of benefiting from synergic effects of the central warehouse and the "call-off" system, short lead-time in materials supplying is achieved. The lead-time is reduced to one day, which means that supply plans are made only one day ahead and supply plans are more flexible.

Since the construction industry is special, each project is unique and lots of factors influence the process during the project life cycle. It is impossible for the company to plan the whole project process accurately and it is difficult to follow the schedule perfectly. With the short lead-time, any changes in the schedule during the project period cause problems in future production, planning and etc.. But the suppliers would like to help to solve problems when they occur. Because there are normally several suppliers for a specific product or material and supply chains of the construction industry are built to meet the construction company's requirements. Thus, the company is generally satisfied with it, even though the short lead-time generates problems sometimes.

4.1.4 Better relationships with some key suppliers

The interviewee confirmed that relationship is extremely important when working in a complex industry like the construction industry. There are four types of suppliers, and two of them require special attentions. In general, with the fact that lots of non-critical items suppliers, as categorized in the Kraljic model (1983), are found, the company naturally dominates the relationship and obtains the control power within these business areas; the company is more intended to develop better relationships with strategic items suppliers, as categorized by Kraljic (1983).

But the interviewee also mentioned that they have noticed the importance of a suitable relationship with its suppliers, and the company would like every party to be satisfied in the project team, so that better cooperation will be realized.

4.1.5 Better planning is needed

Even though it is difficult to plan accurately in the construction industry due to its characteristic, still better planning could be done if people could have an overall view of the whole production process. The construction company should be able to accurately send out real-time information such as forecast of materials requirements concerning what, when and where are needed. Schedules concerning production must be well structured, and there should be systems to support handling information so that breakdowns, of what, when and where the materials are needed, could be done.

The best case that the demands forecast will be developed from long periodical notices to short and specific notices concerning the exact time, amount and places that need to be delivered to. And the suppliers should also have the ability to handle this information as well. And if everyone that participates within the supply chain could be more professional, then the size of warehouse and inventory levels could be reduced by one quarter. The major problem here is there are no routines and systems to make the breakdown which means that there is no computer system to further develop the information to appropriate level.

4.2 The case of company B

The company B operates as both an internal supplier for a leading international project development and construction company and an ordinary supplier to external customers as well. The company supplies both low value products (gravel) and higher value products (concrete and asphalt) to its clients and covers the western region of Sweden. In addition, it has its own quarries and factories in the region.

The interviewee works as a quality coordinator and responsible for environmental issues. He is also in charge of the coordination of production plants in the western region. The interviewee has certain experiences and knowledge of the supply activities within this field.

4.2.1 The warehouse system

Due to the fact that, the company B's products are mostly either supplied in huge volume (such as gravel) or are time-dependant (for instance concrete and asphalt), there is normally no on-site storage or warehouse from the customers' side but a central one owned by the company B itself.

In the company's warehouse, its products such as gravel, and raw materials of time-dependant products are prepared and stored according to its manufacturing plan. Its warehouse serves both ordinary customers, customers that request its products according to agreed plans, and un-planned customers, customers that suddenly send in offers and request to supply with materials immediately.

4.2.2 The information system and communication

The information system used in the company to communicate with its customers is very traditional. Fax and telephone are the typical communication techniques that the company uses to contact its customers. For large projects, the company receives preliminary information of materials requirements from its customers and detailed information is communicated in the project meetings during the project period.

The interviewee pointed several problems with information sharing and communication in the chain. Firstly, there are too many parties involved and it could be very difficult to have effective information sharing. Secondly, the information concerning changes or delays normally arrives late at the suppliers' side since they are quite down in the bottom of the supply chain. Thirdly, the whole industry operates in an open environment in supply chains and companies would like to keep their information concerning production, inventory and etc. safely.

The interviewee fully understood the advantages of an EDI system and was impressed, but he explained this system is far too advanced to the company. It takes time to merge the EDI system into the company's existing organization. The system requires certain investments at it initial stage. And not all the company's customers have the EDI system

in their own organizations. Thus, the interviewee explained that the EDI is still too early for them.

4.2.3 The production planning

The interviewee explained that the company's production always has to be prepared for extra/rush-in orders from time to time. Because, compared with predictable large orders, small amount of sales that can not be foreseen are required to satisfy some of its customers' emergency needs. In this case, the customers will have to be charged with higher price. Since the company is normally given with quite a short-notice-time before the products should be delivered, and this could cause troubles to the company's ordinary production and supply.

The company's production schedule is mainly based on the information from project start-up meetings and follow-up communication. The interviewee stated that the accuracy of material requirements concerning product information, product quantity, and time are critical to plan for a smooth production and supply. He further mentioned that some customers provide information in a very late stage. And changes of project schedules, which result in ordering variations to the interviewee's company, are generally found from the company's customers' side and/or the construction companies' side. These consequently cause major problems to the company's production because the company normally only has limited time to respond to these changes.

Therefore, the interviewee suggested that there should be a close and enhanced cooperation with its customers, so that the company could obtain necessary information on time and accurately. He argued that transparent information sharing could facilitate the entire industry to ease the problems caused by corrections in production schedules, since companies could predict potential changes as soon as they occur. The interviewee also stated that it will be beneficial if reliable ordering information could be provided both in the early stage and during the project period. The interviewee said "the best case for the company is to have a smooth demand, supply and production".

4.2.4 Other findings

Since the company provides low-value products and as a supplier locates down in the bottom of the supply chain in the construction sector, the interviewee mentioned that the company has a relatively low influence in the chain. He also explained that competitive prices are still critical for the company to secure its business, even if it is originally established as an internal supplier of a leading construction company. In order to become an essential member in the supply chain, the interviewee pointed out that the company should extend its business areas which mean either to provide more valuable products or to supply with more types of products.

The interviewee further suggested that the company should establish closer relationships with its suppliers, so that its businesses will be secured. And reliable relationships with customers are important to build trust in supply chains which enable transparent information sharing. The interviewee also pointed out that with reliable relationships and

cooperation, the company is interested in building up a more effective information/communication system; otherwise, it is not beneficial to set up a system which is potentially only used once or a few times. And within an enterprise based system, a proper communication system could be good to use since the system will be kind of fixed and a wide range of people could get access to it.

4.3 The case of company C

The company C is a certified construction logistics provider. The company helps its clients to handle building materials in a new and more effective way, which consequently provide economical benefits to its customers. It offers services in training, supports, consultancy and customer designs in relations to materials logistics and supply activities. The company helps to supply building materials at the right time in the right place with the right size, and its employees work in the evening so that disruptions to the production are minimized. Most of the company's businesses are found in major cities in Sweden and Norway.

The interviewee is a previous civil engineering student from Chalmers. He had his bachelor thesis at the company and got hired when doing his master thesis. He works as a kind of quality insurance engineer, develop business and responsible for the recruitment of new students in the company. And in typical projects, the interviewee mostly works in the pre-phase of a project. At the beginning of projects, he works mostly as a contact person requiring, receiving and sharing information, visiting clients and preparing tender materials. During the projects he works as kind of quality insurance engineer to make sure everything has and will be done correspondent with the contract. For big projects, when there is logistics coordinator/planner from the company on site, he is also responsible for requiring information from them and passing the knowledge learned from sites to sites.

4.3.1 The company C and construction companies

The company currently has two major roles in supply chains in the construction industry. It acts as a logistics planner and a coordinator of logistics activities on site. As a logistics planner, services of logistics analysis are provided in the form as suggestions for effective plans and execute logistics activities for projects based on information provided by its customers, such as blue prints. In addition, the company also calculates figures to persuade its customers that its services are cost-effective to pay for. As a logistics coordinator, the company helps its customers to deliver materials on site during the evenings to ensure the sufficient use of materials for the next day. With this service, the unexpected disturbances and wastes of labour resources on site concerning logistics activities are reduced to the lowest level, since all necessary logistics activities are already done before the site labours start their daily works.

The interviewee stated that the company would like to take a more important role in the project and supply chains. The company plans to obtain more business early in the project planning phase. The interviewee indicated that their professional knowledge facilitates construction companies with effective planning in logistics and material supply activities, since the company has better understanding and more experienced in logistics under various conditions.

Temporary relationships exist when the company is required for services as a problem fixer. In this circumstance, the company is only contacted when logistics problems occur on site, and normally causes more extra work for both the company and the construction company itself. Formal standard relationships are found when the company is purchased

for its competences, for instance, the company's ability to work as extra labour forces to handle materials, the company's expert knowledge in logistics activities and issues, and etc..

4.3.2 The company and material suppliers

There are suppliers that are interested in having businesses/collaborations with the company although there are no formal paper agreements yet. In this case, the company could obtain better knowledge of materials and material suppliers. And as a result, the company could offer professional suggestions of building materials to construction companies based on the quality of materials and the quality of suppliers' services. However, some material suppliers do not want to cooperate totally for some reasons. One simple example could be some extra payments that are potentially generated by closer cooperation.

The company would like to work together with suppliers, but there are some difficulties as well. For instance, these new businesses/cooperation have to be in Stockholm and Gothenburg area since the company currently concentrates mostly in these two area. Due to the current situation of the company, the interviewee is also not sure to expand their services now instead of focusing on their current own business on site.

However, the company is preparing for new collaborations with material suppliers. The company has started education programs with some material suppliers, so that reliable information of suppliers and their products, better understanding and other relevant knowledge will be obtained.

The interviewee also indicated that construction companies' intentions are the dominant factors in defining the cooperation and the relationships with the interviewee's company. In addition the construction companies' intentions are in most cases decided by their project managers, since they are totally responsible for operating projects.

4.3.3 The information and/or communication system

The traditional way of information sharing, such as phone calls, project meetings, site observations, and etc. between the company and its customers are found. Normally, there are only communications between the company and construction companies. But there is hardly any communication between the company and materials suppliers unless problems occur. Because materials suppliers are selected by construction companies and are only responsible for construction companies.

The interviewee expressed that some construction companies only provide limited information since they do not have sufficient knowledge within logistics. In general, he also stated that information is always difficult to obtain on time. "Construction companies have massive aspects that need to be considered and logistics are only considered to be something as to solve problems when they occur" said the interviewee, and he also mentioned that the company needs to contact its customers for requiring necessary information.

The interviewee mentioned that there are lots of problems with information sharing between the company and material suppliers, for instance, inadequate information, late-arriving information and etc.. The major cause of problems is that there is no formal/contractual relationship between the company and its customers' suppliers. The interviewee stated that it will be very helpful if the responsibility of securing effective communication is written as a clause in the contract. He also indicated that if a closer cooperation and/or a longer relationship are established, the above mentioned problems could be solved and enables better performance of logistics and more financial profits.

The interviewee expressed that he has noticed that there are EDI systems used between construction companies and material suppliers, and he also fully realized the benefits of this system such as enables effective and transparent communication. However, the interviewee noticed that an EDI system is very complex and very expensive to develop, and his company interests in getting access to it but not to develop it at the current stage.

4.3.4 The planning system

The company currently plans its own schedule with the information provided by construction companies, and rarely coordinates with suppliers since there is nearly no communication between suppliers and the company unless special situations, such as delay of delivering materials, suddenly change of quantity and etc., occur.

The company has launched an internet based labour scheduling system recently and the system is still under development. The company's employees, especially on site employees, register themselves in the system with information concerning their abilities and status of working and etc.. An adequate implementation of this online system should help the company planning and operating effectively. However, the interviewee indicated that the result from this system is currently not impressive. It is complex, expensive and time consuming to develop. The employees need more training/education programs and the administrative staffs need more experiences to ensure the proper use of this system.

The interviewee explained that an integrated planning within the project team will offer many benefits to participants of a project, since it maximizes the possibility of being noticed of other participants' production changes in the earliest stage so that all participants could adjust their own schedules accordingly with minimized negative impacts. Integrated planning enables closer cooperation among project participants and optimizes project team's performance in total, since project participants work together as one unit. The interviewee also believed that there are opportunities for the company to be more involved in the project concerning logistics. Some construction companies have relatively fewer employees, and they would like to purchase for consultants and logistics companies' competences/professional knowledge to improve the efficiency of the construction industry in logistics.

4.4 The case of company D

The company D is one of the major construction companies in Sweden and was firstly found in 1988. The company has four major divisions: a construction division, an infrastructure division, a division of property development, and a housing division. The infrastructure division supplies products and services used in and around roads. Its business area extends across the entire value chain, from the production of aggregates and asphalt products to paving works and road services. In 2009, the company reported a total sale of SEK 10.3 billion and had more than 4,040 employees.

The interviewee works in the infrastructure division in the Gothenburg area. His working position is above the planning manager but below the regional manager. He has worked in the company for 22 years and purely deals with building roads. The interviewee has 17 years of working experiences outside and 5 years' experiences in offices and has lots of knowledge in logistics and road building.

4.4.1 Interview findings

Few material suppliers are involved in infrastructure projects since fewer materials are used compared with construction projects. The major materials that are used in the project are asphalt, gravel etc.. These materials are not suitable for onsite warehouse system, since these materials are either delivered in huge quantity or are time dependant. And all these materials are produced and provided by sub-organizations in the company. The only material needed to be purchased from external suppliers is the bitumen which is compulsory when producing asphalt. Therefore, with the close relationships among participants in supply chains, open environments for effective and transparent information sharing are enabled.

The interviewee mentioned that there is an integrated online based planning and production system in the company. The entire supply chain is involved in this system and connected via online based information/planning centre. All information concerning the production planning, project status and etc. are stored and transferred via an information centre, in which information is accessible for all project team members. If any changes are made with the project planning, relevant participants will be noticed immediately; and therefore could adjust their own production planning accordingly, so that negative impacts caused by changes are minimized. The interviewee also stated that this system in general improves the overall performance of the whole supply chain by approximately 10 percent. In addition, this system also eases problems concerning communication, planning and etc., since fewer employees are involved in the whole process and negative effects of organizational boundaries are minimized.

According to the interviewee, the working efficiency of supply chains is affected by the physical production system only for about 30 percent, but it is influenced for approximately 70 percent by the ability and attitude of employees. He also indicated that even though the production planning system is great in improving the working efficiency, but the employees still could be improved significantly with the planning and communication. People act differently in the system, because they have different levels of

professional knowledge, experiences and working abilities, and individual goals in projects. Therefore, it is very important to provide trainings to employees concerning the proper use of systems and establishing common goals for projects so that the total working efficiency is optimized.

The integrated planning and production system or the ERP system that is used in the company is illustrated in figure 5.1. And the method of implementing this system could be simply summarized as following:

1. Site manager/planner on site generates the draft of production planning containing the ordering and the use of materials, the status of the project operations, and etc. The information is then sent to the information centre which belongs to the company. Relevant information, for instance materials ordering and production planning, is sent to the employees on site as well to get the confirmation from on site employees in the later stage.
2. Based on the information provided by the site manager, the information centre first finalizes the production planning and sends relevant information to proper participants in the supply chain. For instance, notifications of orders are sent to the manufactory/supplier, and project planning to the site workers.
3. Site employees confirm orders according to the actual consumption of materials and send it to the manufactory via the information centre.
4. The manufactory starts to prepare after notifications of orders are received and produce products when ordering confirmations are received from the information centre. When products are ready, information is sent to the information centre.
5. The information centre contacts the delivery company.
6. The transportation company implements the shipment of materials and keeps contact with the manufactory and the information centre.
7. Materials are delivered to sites and ready to be used by site employees. The first cycle of supply activities is finished and a new cycle is started.

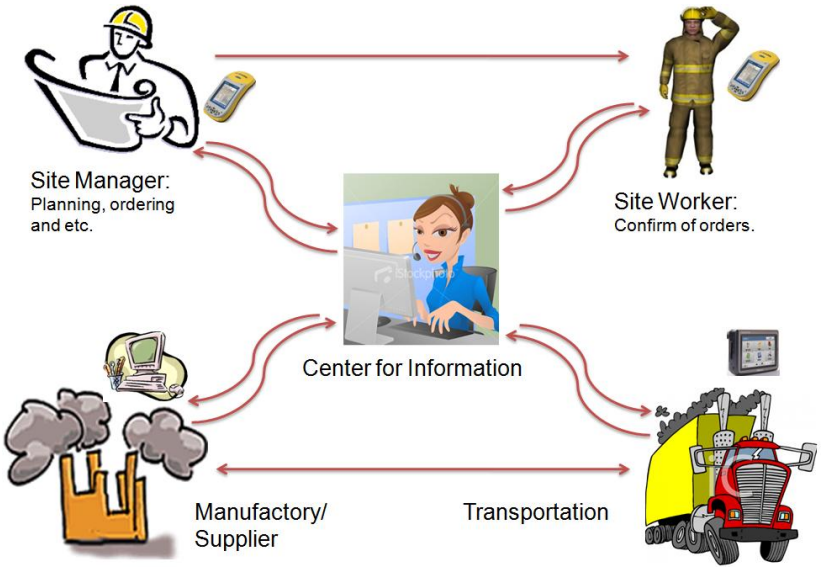

Figure 5.1 Sample of the company's planning and production system, and the flow of information

5 Discussions

5.1 The supplier intention with VMI

The interviewed supplier indicated that suppliers could involve early in the project planning phase and facilitate construction companies to plan and work effectively by their professional knowledge when VMI is successfully adapted. The author believes that this is a major benefit that suppliers could gain from VMI implementations. Because they are able to notice any changes from construction companies' original production plans, which enable the possibility for suppliers to correct their production plans accordingly as early as they can, so that negative effects of un-expected changes are minimized.

Regarding the unsatisfied condition of communication for the interviewed supplier, proper communication systems, which are naturally established when VMI is implemented, to assist suppliers to obtain necessary information as early as possible could be built. The information is processed immediately as it is available in an effective and transparent information/communication system (potentially the EDI system) and information is accessible for participants with a successive VMI adaptation.

The author believes that relationships and cooperation between suppliers and construction companies are enhanced in a VMI circumstance, which means that suppliers could secure their business with construction companies and obtain reliable and smooth demand/orders. Suppliers could be generally interested in the VMI approach because the supplier will have more businesses and influences in supply chains when VMI is successfully adapted. Nevertheless, strategic item suppliers (Kraljic, 1983) might not be motivated by closer cooperation and/or relationships since they are the dominate party in cooperation in the supply chain.

However, according to the interviewed supplier, they have to expand their business areas or coordinate with other suppliers first. The interviewee felt the company has less power and fewer influences than other suppliers in the supply chain, since there are many other suppliers that provide the same products and the products are low-valued and non-critical. Therefore, the supplier stated that it is important for his company to develop itself first. However, he further indicated that VMI should be suitable for strategic items suppliers or suppliers that provide standard and frequently used materials with the regard of construction companies' willingness of cooperation.

5.2 The construction company's intention with VMI

The interviewed construction company has adverse opinions when dealing with different suppliers. With the strategic item suppliers (Kraljic, 1983), companies are interested in securing supply from suppliers and interested in developing a closer relationship with them. The author believes that the company has interests in having more cooperation and closer relationships with this type of suppliers, and thus would like to try the VMI approach with these suppliers. However, as the interviewee mentioned with non-critical items suppliers (Kraljic, 1983), companies enjoy the current competitive environment in this area as companies interest in seeking the most competitive price from various

suppliers. Therefore, the author notices that the company enjoys the power of leading trades in this area and does not want to lose the power of bargain with suppliers, which potentially would be difficult to be motivated by VMI.

According to the interviewee, the company is fully aware of the importance of transparent information sharing and effective communication. The company is satisfied with its current EDI system, even if it is complex and expensive to implement and develop. The author observers that information is inputted and presented in the system and is accessible for relevant participants in the supply chain which means that information is transparent in the supply chains. There are still traditional information and ordering systems in the company, and the interviewee mentioned that the company is trying to have more suppliers involved in it current EDI system. Further, the interviewee concluded that the company offers business incentives to new suppliers that engage in its current EDI system, and the company has certain goals concerning levels of suppliers involved in its EDI system. The author believes that the best way to motivate new implementers into the existing organizational EDI system is to support them with both short-term and long-term financial and technical assistances; at the meanwhile, it is also important to present benefits of EDI systems to new implementers and help them to realize these benefits.

5.3 The logistics company's intention with VMI

The interviewed logistics company is interested in developing its relationships with construction companies and suppliers in supply chains. Both the interviewee and the author believes that close relationships and long term collaborations with suppliers help the logistics company to provide more professional consultancies and more efficient solutions to construction companies in the planning and the construction phase concerning logistics and supply chain managements. Developing closer relationships with construction companies is beneficial for both logistics companies and construction companies as long term cooperation and services are secured, and also because it is easier to build a stable project team concerning its structure and its members. With better relationships and long term cooperation, it is easier for participants to agree on common goals, develop together, and improve the overall working efficiency of the construction industry.

The interviewee also indicated that they still have a negative opinion with the EDI system, even though the logistics company suffers problems with sharing information. However, the author believes that if existing EDI implementers, such as construction companies and etc., could offer some financial and technical assistance, which is exactly what the interviewed construction company is doing now; the logistics company is then should be interested in adapting EDI system into their organizations. In order to ensure the effective use of EDI systems, it is highly important to equip companies' employees with sufficient and adequate education programs. Both companies and their employees have to be patient with problems that occur during the process and be patient with time.

The EDI system, according to some interviewees, provides a false impression that it only facilitates with the short term planning, since order confirmations are sent just few days ahead the time that products/materials are needed. But the truth is that, there are early

notifications of orders as early as in the beginning of projects when certain needs of products/materials are cognizant of; changes of ordering status are adjusted according to the latest condition of projects; and finally, final orders are made and sent to suppliers. Thus, the EDI system actually provides information to plan in both short-term and long-term.

5.4 Lessons learned from the infrastructure company

The author notices that even though there are much more suppliers in the construction industry compared with the infrastructure industry and construction companies would like to purchase from external suppliers, still construction companies should try to cooperate with their internal suppliers instead of still buying products from the outside of the company to gain the guarantee of price, quality and quantity of products. Internal cooperation will be beneficial for companies in the long run, and this also helps to minimize the number of suppliers in the construction industry and thus the complexity of supply activities is reduced. In addition, with suppliers providing products that are not covered by construction companies' internal suppliers, establishing partnerships will create long term collaborations and provide similar benefits that internal suppliers could offer to construction companies.

5.5 Discussions in general

Top management's commitment is always the most decisive factor when introducing and implementing new management/operational approaches and systems. Without the commitment, sufficient monetary investments and time allowances can not be realized to implement new operational approaches. To obtain top management commitment, it is important to explain benefits of new approaches theoretically and present statistics figure to board of companies.

Another major obstructive factor of an effective operation of supply chain methods is organizational boundaries within the supply chain, which generate negative effects such as isolating organizations from others, protecting organizational information, and etc.. Collaborations with internal suppliers and building partnerships with compulsory external suppliers should help organizations to minimize the limitation of organizational boundaries within the supply chain. With enhanced relationships in supply chains and relevant agreements among organizations, information is shared and received transparently and effectively without the concern of business information leaking. Therefore, the effectiveness of communication in supply chains is improved.

Communication problems are widely found in the construction sector and were pointed by many researchers like Veiseth *et al*. (2003) and Thomas *et al*. (2002). During the interviews performed for this research, interviewees also confirmed this interfering factor. There are several causes for this problem. However, the author believes that employing VMI could be beneficial for all participants in the construction supply chains. Because VMI enables an adequate communication/information sharing channel for all members involved and they guarantee and are guaranteed with transparent and effective

information sharing with formal agreements when the VMI relationship is built. Even though modern and advanced information and communication system is not mandatory for transparent and effective information sharing and communication in the VMI adaptation, still it provides great assistances concerning information processing and communication. However, this kind of system, such as EDI, is expensive. It requires huge investments and continuous development of the system.

Construction logistics and supply chain management suffers problems with fluctuating demand cycles, uncertainty of production conditions, and etc. (Dainty *et al*., 2001); meanwhile, one of the major benefits that VMI could bring into the construction sector is that, it helps to eliminate bullwhip effects (e.g., Lee *et al*., 1997; Disney and Towill, 2003), which are believed to be one of the major causes of fluctuating demands in supply chains by the author. Since within VMI relationships intermediator are minimized to the lowest level, VMI also facilitates in minimizing sizes/lengths of supply chains, which means that suppliers in the bottom of the chain have closer contact with customers and enable rapid reflections and early notification of customers production condition. Therefore, problems with uncertainty of production conditions are minimized or even eliminated. One of the interviewee also confirmed these by explaining that proper VMI adaptation could help to notice potential changes of customers' demand in a very early stage, which offers opportunities for suppliers to correct their production and a smoother production could be realized.

With a successive implementation of VMI, traditional boundaries among different organizations are weakened since more cooperation is found compared with managing the project's supply chain with other methods. VMI enables the intention of creating and achieving common goals among members in supply chains instead of focusing on their own in the traditional supply chain management system. Members need to communicate in a transparent and effective attitude is ensured, so that a proper transfer of traditional construction companies' responsibilities, such as forecasting and generating orders, to suppliers could be actualized. Moreover, because VMI implementation weakens organizational boundaries and obligations of providing and protecting information are written in VMI agreements. Trusts among members in the construction supply chains are enhanced in a VMI circumstance.

Rush orders, which are considered as another important area influencing the productivity in the construction industry, could be minimized to the lowest level or even totally eliminated in a VMI based construction project. Because, triggers, such as low the quality of information sharing and being isolated from others, are eliminated with the success of VMI implementation. Further, Tanskanen *et al*. (2009) present an excellent improvement in reducing rush orders in their project.

When a successive VMI adaptation is actualized, the myopic controls of logistics and supply activities, which is believed as one of the major causes of low productivities in the construction industry (Vrijhoef and Koskela, 1999), is eliminated or minimized, since members are naturally employed with their core competences within a VMI partnership. For instance, logistics companies are involved for their professional knowledge and experiences in logistics and supply activities, and they also potentially have better knowledge of suppliers' products and services compare with construction companies.

Therefore, unprofessional activities in the construction supply chains are minimized or eliminated.

In summary, VMI offers opportunities to ease major causes of SCM problems, such as isolating from other members in the supply chain and myopic controls of supply chains, and helps to interfering issues of improving the productivity in the construction sector, for instance, fluctuating demands and rush orders. Therefore, there is a solid ground to motivate the implementation of VMI. VMI should be applicable in the construction industry; however, since supply chains in the construction industry are unique, it is important to distinguish different needs and intentions from participants in supply chains and introduce and implement the VMI with different strategies.

Regarding operating VMI in a global circumstance, it could be difficult to implement VMI in an international condition compare with a local or regional range. Because, for instances, members in the construction industry traditionally focus on their own individual goals and are strenuous to open and build trust with other members. Moreover, there is still currently lack of standard procedures of implementing VMI in the construction sector. Therefore, the author suggests to testing the VMI adaptation and design common standardized procedures first in a relatively small region; then it could be extended to a larger circumstance.

6 Conclusions and Recommendations

There is huge number of suppliers in supply chains in the construction industry. Every supplier has their own interests and goals which increase the complexity of logistics and supply chain activities. In addition, construction projects are unique and there are many types of projects. Thus, it is difficult for construction companies to utilize experiences learned from other projects as construction projects are managed and operated by project managers, who are normally having limited experiences with logistics and supply chain activities for similar types of projects, and project managers traditionally have too many things to consider at the same time. With the regards of VMI benefits and empirical findings, VMI could facilitate in solving logistics and supply chain management related problems and should be applicable in the construction industry. However, at the current stage, implementing VMI with non-critical suppliers is not practical and has to be patient until they obtain more businesses or become more influential in the supply chains in the construction industry.

VMI is considered as a successful logistics and supply chain management approach to implement and learn from other industries such as the automotive industry, the grocery industry etc.. There is less number of suppliers involved in industries like automotive. The complexity of supply chains' activities and relationships of supply chain participants is in a comparatively lower level compared with the construction industry. It is difficult for construction companies to administer the implementation of VMI. Thus, logistics companies should be hired when implementing VMI in the construction industry for their professional knowledge to ease logistics problems and manage collaborations among supply chain members. Moreover, necessary adjustments with the structure of supply chains have to be done. For instance, unifying suppliers within the range of the non-critical items, extend supplies/business areas of non-critical items suppliers, and etc..

VMI adaptations in the construction industry have to been performed step by step, since construction companies have different intentions towards the VMI and the industry's logistics and supply chains' activities are unique compare with other industries. In order to ensure the VMI implementations in the construction sector to be consolidated at every step, following suggestions are recommended:

- Construction companies should ensure the maximum use of their internal suppliers, since less resistance of organizational boundaries is found when different organizations operate within one enterprise. Considering the current situation, construction companies' internal suppliers feel that there are needs of more cooperation between the construction company and supplier. Internal suppliers of construction companies are the most suitable suppliers to initiate VMI relationships, since it is easy to build trusts, establish common goals and etc..
- Establish partnerships and extend cooperation among construction companies and external suppliers when external suppliers are compulsory in construction projects. When internal suppliers are not available or certain products that have to be purchased from external suppliers, the partnership, which aims to build trusts and obtaining more cooperation, is the best way to weaken negative effects of organizational boundaries. The partnership is the most proper way to obtain transparent and effective communication and improve cooperation for the

medium and/or small size construction companies. However, this does not necessarily mean that no partnerships should be built for major construction companies.

- EDI and ERP system are suggested to use with major construction companies and their suppliers. Construction companies that already have these systems should try to introduce them to their suppliers and encourage suppliers to involve in the systems by offering incentives. For medium or small sizes construction companies, it is difficult for them to establish their own EDI and ERP system since these systems are expensive and complex to be implemented. In this case, smaller construction companies could try to involve in major construction companies' systems and be patient with developing their own.
- An integrated planning with all participants involved in supply chains should be considered and is suggested to be performed, so that efficiency of the entire supply chain will be maximized. Because an integrated planning enables the possibility for the entire supply chain to perform as one entity to achieve common goals instead of focusing on their individual goals.
- Starts to implement VMI with suppliers of simple, standard and most frequent used building materials/products, such as the project done by Tanskanen *et al.* (2009) in Finland, to obtain necessary experiences of merging VMI into the construction industry. Logistics and supply chains activities are unique in the construction sector; start with simple testing projects facilitates the industry in obtaining relevant experiences and establishing common standards.
- Design standard procedures of implementing VMI in the construction industry, and evaluate and develop it continuously during the process. VMI is a rather new method in the construction logistics and supply chain management, it is important to create common standard procedures for future projects. In addition, continuous developments of VMI implementations have to be done so that procedures are evaluated and imperfections are discovered; which consequently results in improving the efficiency of supply chains activities perpetually.
- Motivate further VMI implementations in the construction industry with other suppliers of building materials/products by actual figures which present improvements in the working efficiency the whole supply chain.
- Logistics companies transform to VMI companies by cooperate closely with suppliers and involve early in the start of project period. Traditionally, logistics companies only coordinate supply activities of building materials. But when logistics companies are employed in VMI partnerships, more obligations/responsibilities are transferred to them and further businesses are gained. Thus, VMI companies are found.
- Unifying non-critical item suppliers (Kraljic 1983), so that the number of suppliers within this area will be decreased and the complexity of logistics and the supply chain's activities is reduced as well. Both construction companies and non-critical item suppliers indicated that it is difficult to implement VMI in the non-critical supply pattern for several reasons. Lack of influences is the underlying causes, which could be solved if suppliers are unified within the non-critical items supply area.

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