

# AN ANALYSIS OF THE LIFE-CYCLE CURTAIN WALL PROCESS THROUGH SUPPLY CHAIN MANAGEMENT

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## ABSTRACT

This paper presents a research project named “Automated life-cycle management system for curtain walls in high-rise buildings based on supply chain management,” which is jointly performed by the consortium of universities and companies involved in curtain wall design, manufacturing, and construction in Korea. The objective of this research is to improve the efficiency of the current process through the application of SCM to the C/W life-cycle. In this paper, the research results at the early stage are presented with a focus on the analysis of problems and waste in the life-cycle of the curtain wall supply chain spanning from design to construction, and to operation and maintenance. The results show that most of the problems and waste are caused by poor collaboration, information sharing, communication, and coordination among actors in the supply chain of the project life-cycle. Finally, future research issues are briefly discussed.

## KEY WORDS

Curtain Wall, Process Model, Supply Chain Management, Value Stream Analysis, Information Management

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## **INTRODUCTION**

In high-rise building construction projects, curtain walls are one of the most widely used exterior finishing components as well as the key management factors in cost and schedule control. Generally it occupies about 10-15% of a total project cost, and its construction process lies on the critical path. The life-cycle process of curtain walls involves many actors, such as the owner, architect, contractor, curtain wall consultants, specialty contractors, and manufacturers, with information and material/product flow being shared and exchanged among them. However the fragmentation of the process results in inefficiency in project control and management. Although several research projects have been conducted for the improvement of the C/W construction process (Ahn et al. 2001, Lim 2002), they did not consider the overall C/W supply chain since their focuses were mainly on the construction process.

Therefore, the objective of this research is to improve efficiency and productivity of the whole curtain wall (C/W) process based on the supply chain management (SCM) concept. To do this, the life-cycle supply chain from design to construction, and operation and maintenance of C/Ws was analyzed to derive problems and waste in the material, parts, product, and information flow. Since this research is still on-going, the results at the early stage are presented with a focus on the problems and waste in the supply-chain of the C/W life-cycle. Finally, future research issues are briefly discussed.

## **RESEARCH SCOPE AND METHODOLOGY**

This research focuses on the unit system where the C/W systems can be classified into unit, stick, unit and stick, and panel systems based on the assembly method. In addition, this research focuses on the outsourcing-based service system rather than the total service system, which covers design, production, fabrication, packing, delivery, installation and maintenance conducted by one company.

For the unit system under the outsourcing-based manufacturing environment, the parts of a C/W unit are produced by different manufacturers, so the process requires longer lead time to C/W construction and stricter requirements regarding constructability compared to the stick system. However, high and consistent quality requirements, time pressure in the project schedule, advantages in construction safety, and an increase in construction labor costs have made the unit system more popular, particularly in skyscraper construction. This research aims at proposing a to-be model for the life-cycle C/W process by analyzing the process to reduce uncertainties and waste based on the aspect of supply chain management (SCM). Therefore, this paper consists of the following topics:

- 1) Existing research and case studies are analyzed through a literature survey on C/Ws and SCM.
- 2) The as-is process and problems are identified through site visits, surveys, and interviews with relevant practitioners
- 3) Future research is proposed to improve the current process and to resolve the problems, and some conclusions are drawn.

## SCM IN THE CONSTRUCTION INDUSTRY

Handfield and Nichols (1999) define that “the supply chain encompasses all activities associated with the flow and transformation of goods from the raw materials stage, through to the end user, as well as the associated information flow. Material and information flow both up and down the supply chain.” They also define that “supply chain management (SCM) is the integration of these activities through improved supply chain relationships, to achieve a sustainable competitive advantage.”

Although the concept of SCM was initiated from the manufacturing industry, studies on the application of SCM in construction (O’Brien 1998, Vrijhoef and Koskela 2000) have shown great potential for improvement in the construction supply chain along with suggestions for other applicable areas of SCM. We also believe that the application of SCM in the C/W life-cycle process could improve efficiency of the overall supply chain for the stakeholders, such as the owner, architects, engineers, constructors, subcontractors, and suppliers.

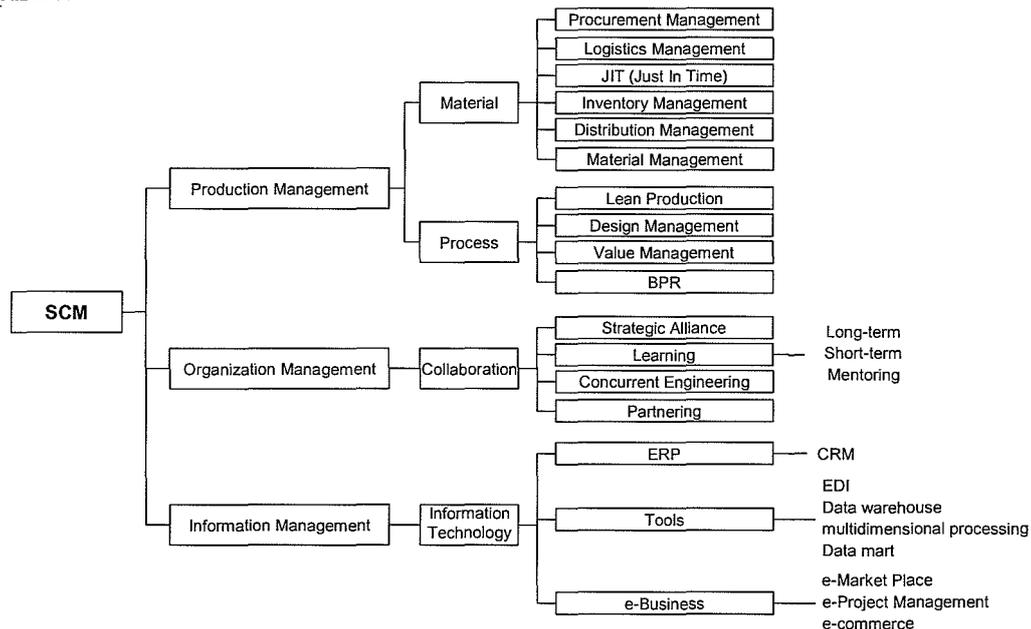


Figure 1: Three categories of SCM (Park et al. 2003)

As shown in Figure 1, the various concepts involved in SCM can be classified into three categories: 1) production management using various management methods and techniques, 2) organization management for mutual cooperation between actors that make up the supply chain, and 3) information management that supports integrated management through communications among actors in the supply chain (Park et al. 2003). Based on these categories of SCM, this research analyzed the life-cycle process of curtain walls. The ultimate goals of this research include building a to-be model for the curtain wall supply-chain management throughout the project life-cycle. However, as this is still an on-going project, this paper represents only some of the preliminary results.

## **SUPPLY CHAIN IN THE LIFE-CYCLE PROCESS OF CURTAIN WALL**

A curtain wall (C/W) is a non-load bearing wall that is prefabricated in a factory and then installed at a construction site. The C/W construction process is usually on the critical path of a project schedule, and it is a heavy load component that can determine the capacity of hoists at construction sites. Typically the life-cycle of a C/W includes architectural design, C/W design, procurement, assembly, and maintenance phases. Over 30 participants, such as the architect firm, engineering design firm, C/W consultant, manufacturer, and constructor, are involved throughout the life-cycle. Material/product and information flow needs to be well coordinated among these actors throughout the life-cycle so that the right materials, parts, and units, along with right information, can arrive at the right place at the right time.

C/Ws can be classified by various material types, such as metal, precast concrete, etc., and they can also be divided into stick and unit systems based on assembly time and procurement method. More high-rise buildings use the metal C/W system rather than the precast C/W system due to quality, cost, and constructability. The use of metal unit systems has been increasingly popular in high-rise building construction in Korea. In terms of the assembly method, either the stick wall or the unit wall system is selected by comparing site conditions, cost, and construction schedules with the pros and cons of each system. However, recent trends in Korea show that many of high-rise buildings of over 30-stories adopted the unit wall system because of the ease of installation and high quality of C/W units.

Manufacturing system can be divided into two categories: total service systems (TSS) and outsourcing-based service systems (OSS). As shown in Figure 2, TSS directly operates engineering, most of the manufacturing process including extrusions, parts production and assembly, and construction, while OSS directly operates engineering and construction only; manufacturing is outsourced to several subcontractors. This research focuses on the unit wall system that is manufactured under OSS, because there has been tendency for the C/W manufacturing process to migrate from TSS to OSS. In Korea, as of 2004, there is only one company that can provide total service, all other companies produce C/Ws under OSS. OSS has become more popular due to the various barriers of TSS, such as the heavy investments needed for factories, decreases or inconsistency in operation rate due to fluctuations in contract awards, increases in labor cost, etc. However OSS is not always advantageous; it can cause problems, since more actors are involved in the supply chain process, such as long lead time in material/part/unit flow, excessive inventory, and information loss and redundancy.

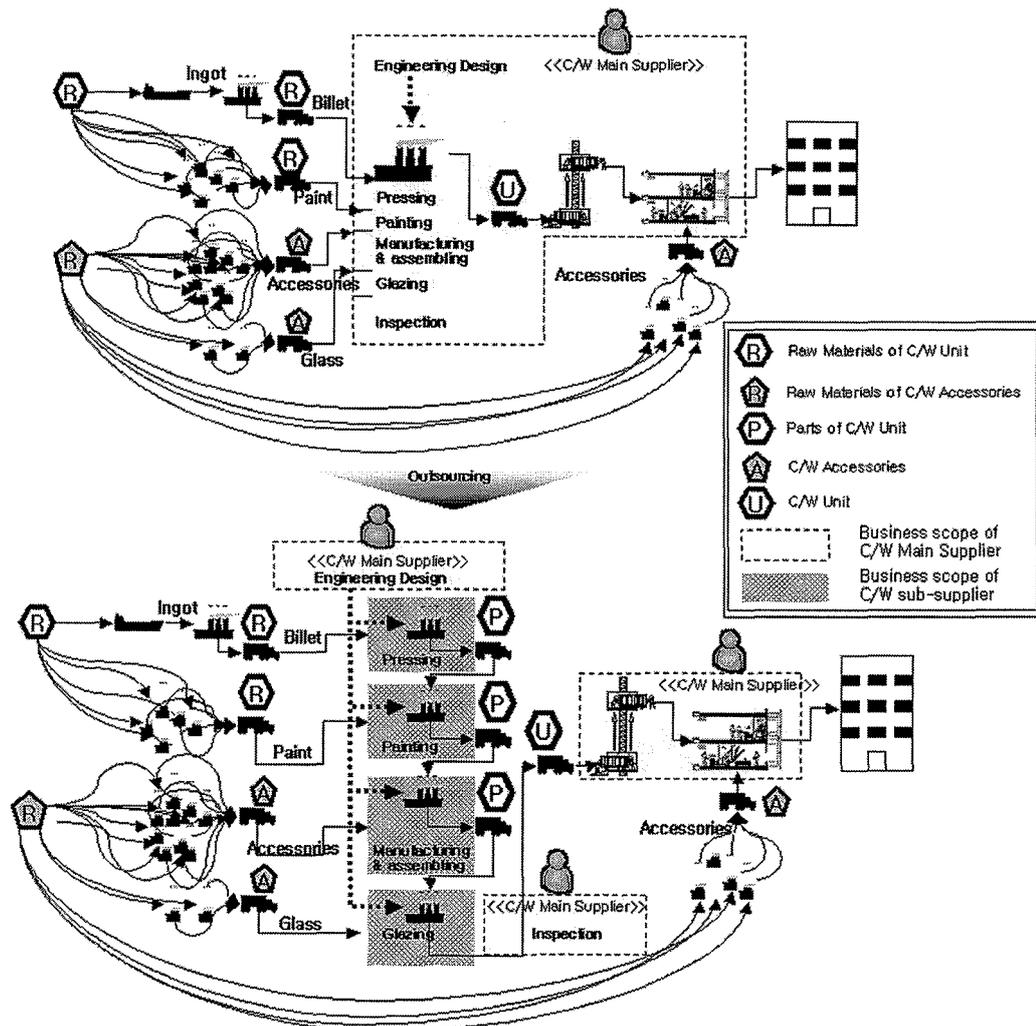


Figure 2: Total service system and outsourcing-based service system

Therefore, this research has identified problems and waste under OSS based on SCM aspects in order to reduce time buffer and information waste so that the actors in the curtain wall supply chain collaborate like they would under TSS or even better.

### ANALYSIS ON AS-IS CURTAIN WALL PROCESS

The C/W process has been analyzed through site visits and interviews with experts including the following questions:

- What are the problems and waste in the C/W process? And when do they occur?
- What are the root causes of them?

- Is there any way to resolve or eliminate them through SCM-based process reengineering?

### GENERAL PROCESS OF CURTAIN WALL

A life-cycle process model of C/Ws was developed on the basis of material/product and information flow by using the IDEF0 modeling methodology, as shown in Figure 3. Based on the characteristics of each phase in the life-cycle, the model has four activities (phases) at the top level: design, manufacturing, on-site construction, and maintenance.

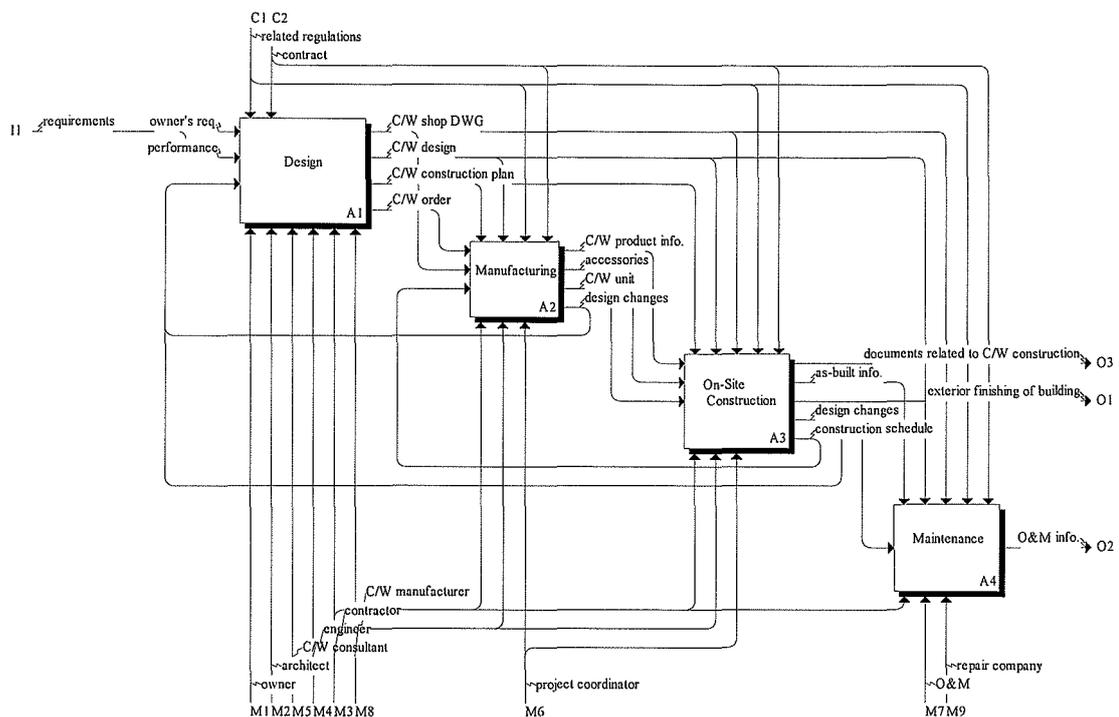


Figure 3: Life-cycle process of curtain walls

The design phase, when the architectural and engineering information of C/Ws is completed, is sub-divided into architectural design and C/W design activities. Information created in the design phase includes facade design, structural design, criteria setup for required performance, material, fastener and joint details, and many other aspects that cover both architectural and engineering designs.

The manufacturing phase, as shown in Figure 4, consists of two sub-phases: manufacturing C/Ws and supplying parts sub-phases. The manufacturing C/Ws phase is, in turn, sub-divided into sub-processes, such as pressing, painting, cutting, assembling, glazing, packing, inspection, and delivery to make a C/W unit. As each of them phase can be processed at a different time and places, there are two types of production systems, such as: the total service system (TSS) whose where all processes are done in one factory, and the outsourcing-based service system (OSS) whose where many processes are subcontracted to different factories. OSS is getting becoming more popular in for C/W productions, since it

has advantages in cost infrom the manufacturer's point of view. However, this system needs several actors to participate in each phase of the C/W life-cycle, so the total number of actors involved is often exceeds approximately over thirty excluding the owner and the general contractor. As a result, it usually has longer lead time between actors due to the problems of material and information flow.

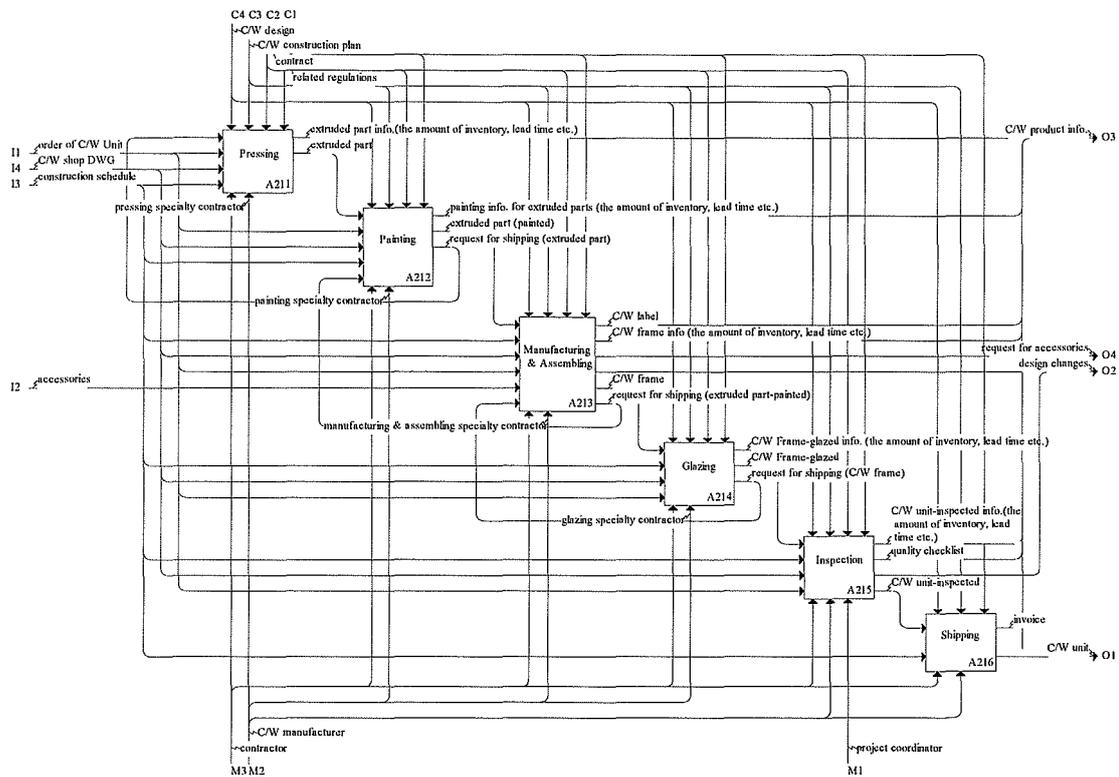


Figure 4: Manufacturing process of curtain walls

Information on the shipping of C/Ws to the construction site, which is A216 in Figure 4, includes products and quality inspection, such as the number of C/Ws manufactured, inventory amount, date produced, and inspection results.

The construction phase, (when C/Ws are installed at the site,) is sub-divided into hoisting and installation processes, as shown in Figure 5. Information created/generated in the hoisting process includes: delivery plan of C/Ws, packing and handling, transportation to and inside the site, stockyard and protectingion plans, labor and equipment plans, etc. Meanwhile, the iInstallation information covers includes as-built data of the C/W, such as unit numbersquantity to be installed, their locations in stockyard, inspection results, etc., according to the installation schedule.

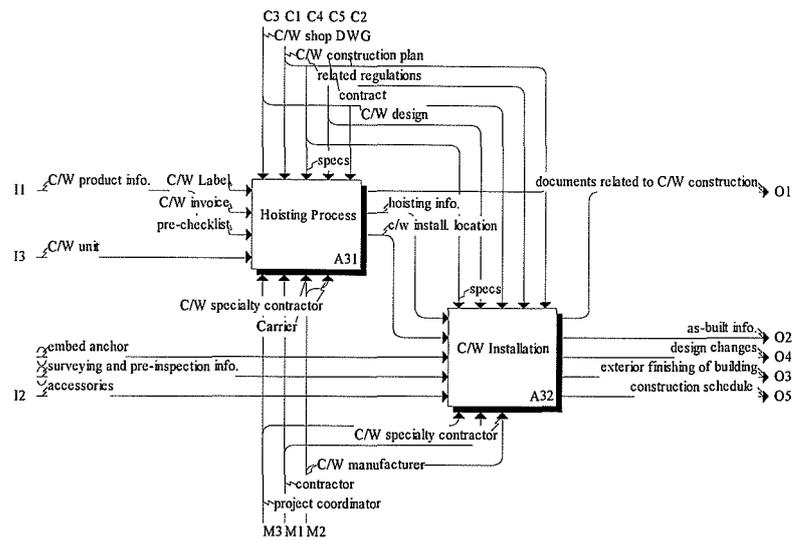


Figure 5: Construction process of curtain walls

## ANALYSIS OF PROBLEMS AND WASTE IN THE CURTAIN WALL PROCESS

If a building project can be managed in based on the process as shown in Figures 3-5 above without time buffersdelays and waste, it will be beneficial to all the actors in the supply chain. But this hardly happens in reality. Therefore, consultants, architects, suppliers, subcontractors, and general contractors related to the C/W process were surveyed and interviewed to findidentify time buffersdelays and to derive problems and waste occurrencesd in the process.

## VALUE STREAM ANALYSIS ON THE C/W SUPPLY CHAIN

To identify and measure the degree of problems and waste in the process, the a value stream analysis on the C/W supply chain is still being performed with a focus on where and how frequently time buffers occur in the C/W process. The value analysis is still on-going at this time, however, the preliminary result showing the time buffer schematically is shown in Figure 6. In For Figure 6, the manufacturing and on-site construction processes are were surveyed on the basis of manufacturing curtain wall units for 5 stories, since manufacturers typically produce the units of 5 –storiesy units at a time in order to keep the operation rates and material/part supplies at a certain level.

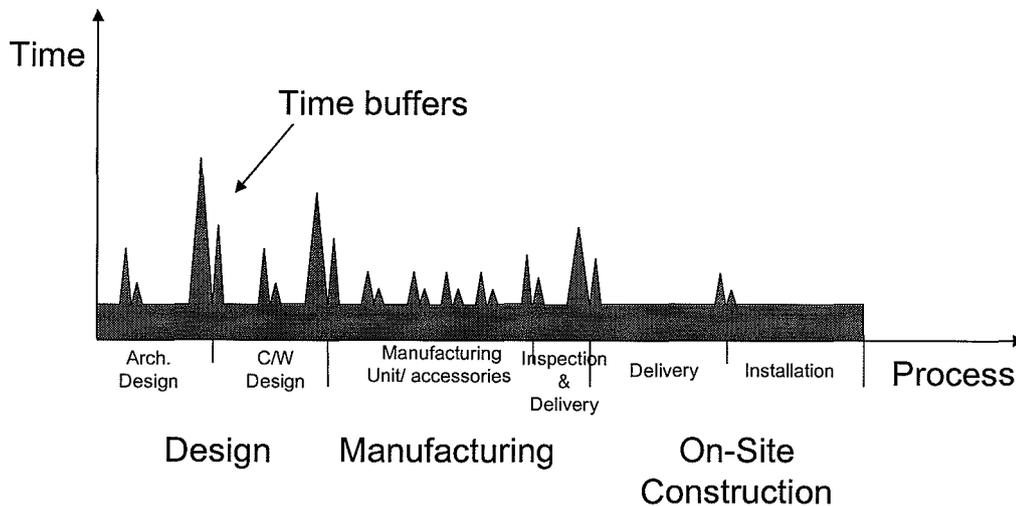


Figure 6: Time buffers in curtain wall process

The results shows that the time buffers caused by inventory management, excessive lead time, and other delays usually occur usually inat the interface between different actors and between different phases of the life-cycle. That is, in the design phase, they occur in the process of approval and transportation of C/W plans between designers and manufacturers; in the manufacturing phase they occur in the process of material/parts and information flow among 1st-tier, and 2nd-tier suppliers and manufacturers; and in the on-site construction process, they occur in transportation, inspection, and information errors of C/Ws between the manufacturer(s) and the constructor/installer at the construction site.

#### CAUSES OF PROBLEMS AND WASTE IN THE C/W PROCESS

Figure 7 shows the problems and waste and their causes in the C/W process based on preliminary results of the value analysis. Figure 7 indicates that the problems and waste are mainly caused by: lack of collaboration and information share at the early phase of the life-cycle, causing design changes in the successive next phase; lack of communication and inefficient management among suppliers and manufacturers, causing delays and long lead time in the material/product flow; lack of coordination and inaccurate planning between constructor and manufacturer, causing reworks, delays, and excessive stocks, and conflicts with other worktasks; and information loss, especially by fragmentation of the process, redundancy, and inaccuracy in the information flow through the life-cycle.

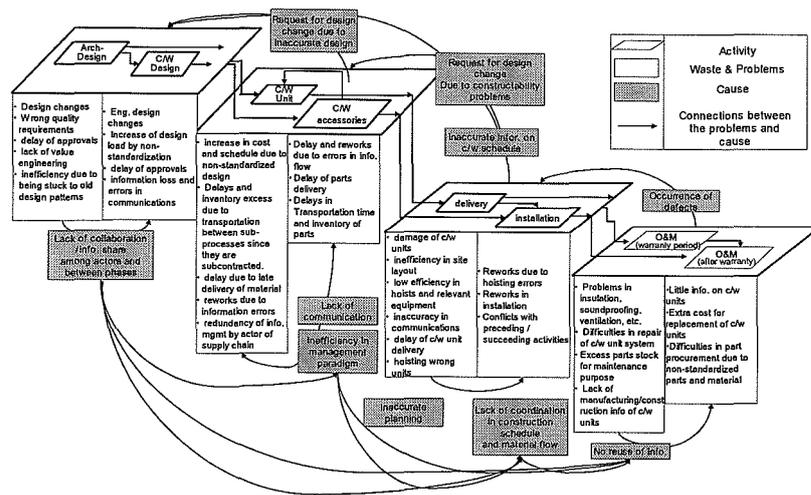


Figure 7: Problems and waste in curtain wall life-cycle

## INFORMATION FRAMEWORK FOR C/W LIFE-CYCLE PROCESS

It can be concluded that the problems and waste encountered in the supply chain of the C/W life-cycle process are caused fairly by information loss and redundancy, difficulties in information sharing and communication, and lack of collaboration and coordination among actors. Therefore it is necessary to build an information framework to support the collaboration among all the actors involved in the C/W life-cycle based on the SCM concept. This would be the most effective way for reengineering the current process since it can reduce lead time, improve service and quality, and reduce cost over the life-cycle.

The information framework would also have to support the integration and share of information beyond the electronic information exchange that is just for logistics among all the actors in the supply chain, spanning from the design to the operation and maintenance phases beyond the electronic information exchange for logistics only. The conceptual presentation of the information framework is shown in Figure 8, and the followings are some of the major research topics that need to be conducted to build the framework.:

- 1) Collaboration environment for the supply chain management through the C/W life-cycle
- 2) Share of C/W information through product and project models
- 3) Product and information flow management through the use of RFID (Radio Frequency Identification) in the manufacturing and on-site construction processes

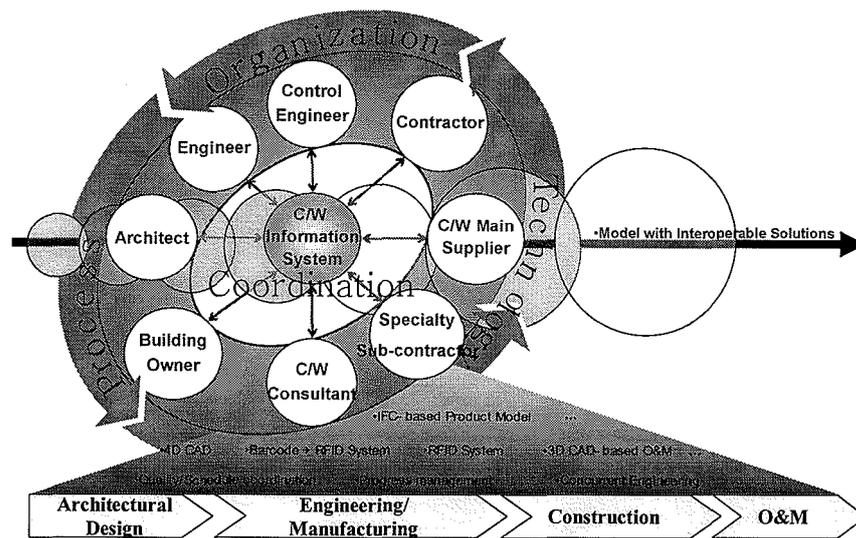


Figure 8: Conceptual presentation of information framework for to-be C/W process

## CONCLUSIONS

This paper presents the a research effort jointly performed by universities and companies in Korea. The objective of the research is to improve the efficiency of the current C/W industry process through the application of SCM to the C/W life-cycle. To do so, this research has identified problems and waste in the C/W supply chain at the preliminary level by analyzing time buffers based onin the as-iscurrent life-cycle process of the unit-based metal C/Ws. As a result, it is found that the most of problems and waste are caused by information loss and redundancy, difficulties in information sharinge and communication, and lack of collaboration and coordination among actors in the supply chain of the C/W life-cycle. To resolve themthese issues, this research proposes the construction of an information framework to resolve the root causes of the problems and waste., and tThe next step of the research is currently in progress and has on-going along with 3 major goals: 1) build a collaboration environment for the C/W life-cycle process; 2) facilitate sharinge of C/W information through product and project models; and 3) improve product and information flow management through the use of RFID in the manufacturing and on-site construction processes. This framework is expected to support not only information management but also product management of the SCM categories mentioned in Figure 1. However, it would have to be accompanied with an appropriate contractual arrangement so that the right actors can be involved at the right time in the supply chain of the C/W life-cycle. The results of the on-going research would will be hopefully shared viain future publications.

## ACKNOWLEDGEMENTS

This research (2003 R&D A01-03) is financially supported jointly by the Ministry of Construction and Transportation of the Korean government, Daelim Industrial Co., Better

Living Space Co., and EasyCM Co. The authors would like to thank the practitioners in the curtain wall supply chain for their interviews and responses to surveys.

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