

Investigation of Influential Factors for the Development of a Lift System Design for High-Rise Building Construction

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ABSTRACT: Bidding for high-rise building projects has been increasing recently in foreign and domestic market. As the size (height) of the construction projects is increasing, the importance of prior planning for the selection of the tower cranes to lift up the construction materials is increasing. Although many researches on lift plan are being actively conducted, there has hardly been any research to determine the number and location of the lifting equipments in real-time basis based on the actual construction data of the change in the lift quantity (lift load).

Accordingly, the objective of this paper is to analyze the influential factors for the development of a program to select the optimum lift equipments for high-rise building at the design stage and to design the optimum concept for this development. This study suggests the alternative for the collection of actual construction data necessary for the development of a system for the selection of optimum lift equipments, and the design factors for this system development are selected in this study. Additionally, the concept design is optimized after examining the methods for the collection and use of actual construction, and the potential problem areas in this process are analyzed through FMEA (Failure Mode Effect Analysis). The result of this study will be used as the foundational data for the future development of the system for the selection of optimum lifting equipments.

Keywords: FMEA; influential factors; high-rise building; tower crane

1. INTRODUCTION

Planning and management of lift is the most essential area of management of high-rise building construction. It is the hypothetical construction plan for the optimum management of materials to use tower cranes and construction lift equipments for vertical transportation of materials and human resources necessary for the construction. According to World Skyscraper Society, construction of

buildings higher than 200m is rapidly increasing since the year of 2000, and the importance of lift management for vertical transportation of materials in high-rise building construction is expected to be greater in the future upon examination of currently developing projects.

Despite the difficulty in the establishment of standardized process for the selection of optimum lift equipments due to the characteristics of construction projects, its importance has called for various researches.

When there is a problem in the lift plan, its revision is almost impossible, resulting in a potential failure of the project. This study derives the optimum concept design for the development of a program to compute the most appropriate number and type of tower cranes for a skyscraper construction project and aims at analyzing potential problems in high-rise building construction projects. The result of this study will be used as a foundation data for future development of a computational program for lift equipments.

The concept diagram and flow of this research is illustrated in figure 1.

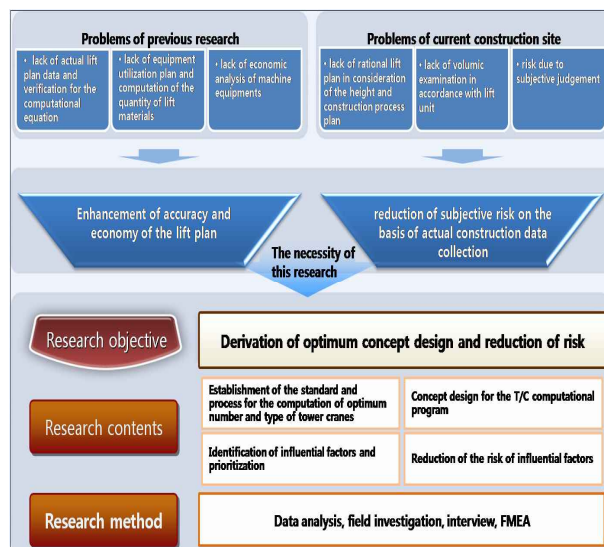


Figure 1: Concept diagram and flow of this research

2. PRELIMINARY ANALYSIS

2.1 Literature review

Most researches on high-rise buildings dealt with projects of 50-floors or below, but this research focused on skyscraper projects in Korea or abroad currently on-going or being planned for in the future. Its reason is to delineate the trend for and influential factors on lift cycle time of lift equipments such as tower cranes. Before carrying out this research, similar researches and existing studies on this area were reviewed.

Many researches on lift plan have already been conducted. Hong, Young-Tak et al. researched on "Evaluation of Time-Affecting Factors in High-Rise Building Construction" (2004) and Kim, Jung-Jin et al. conducted "A Study on the Hoisting Planning System in High-rise Building Construction" (2005). However, these studies were limited on the lift load, number, location, and type of tower cranes and excluded the equipment usage plan, or they dealt with the process of evaluating time-affecting factors in high-rise building construction at the planning stage. Thus, they dealt with topics different from the focus of this research, i.e. prediction of lift cycle.

Additionally, Lee, Jong-Ryul et al. studied "Models for Predicting Hoisting Times of Tower Crane in the High-rise Building Construction" (2004). It dealt with steel bar lift at the site of 17-floor or 18-floor apartment building construction, and it differs from the subject of this research, i.e. high-rise building.

Table I: Comparison of studies on lift plan for high-rise building construction

classification	researcher	topic
lift equipments for high-rise building construction	Lee, Joon-Bok (2008)	• development of a simulation model for the optimum combination of lift equipments related to the construction process
	Kim, Jung-Jin (2005)	• establishment of verification and application system for actual construction data
	Ahn, Byung-Joo (2004)	• suggestion for the alternative to improve the accuracy of the computation of lift quantity based on the construction process plan
	Jung, Yeon-Woo (2004)	• analysis of influential factors on lift in high-rise building construction
	Moon, Min-Sik (2003)	• derivation of influential factors rank and computational equation
	Park, Gil-Jae (2001)	• analysis of characteristics of lift plan for high-rise building
	Ahn, Byung-Joo (2001)	• economic analysis and derivation of optimization method
	Kim, Hoon (1999)	• suggestion for the improvement alternative for problems of lift plan

2.2 Overview of the program for the selection of lift equipments

Early payback on the investment through short construction time is the most important issue for high-rise building construction. The investor can minimize the financial cost through this effort. Accordingly, various alternatives to shorten the frame construction time, which accounts for the large portion of the total construction time and cost, have been proposed. The detail of the process of developing the program to compute the number of tower cranes for the construction of a high-rise building is shown in the following figure 2.

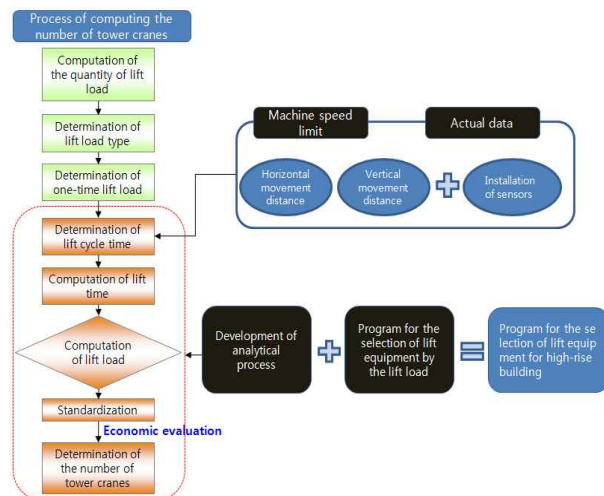


Figure 1: Concept diagram for the process and development of the program to compute the number of tower cranes

3. Analysis of design influential factors

Determination of lift cycle time, which reflects the characteristics of a skyscraper project, is very important in the process of computing the number of tower cranes, which is derived from previous studies. The actual construction data, which are necessary for this determination of lift cycle time, were collected and analyzed by installing sensors on the tower cranes of a domestic construction company at a foreign skyscraper construction site. Additionally, the contents of this research was to be added

and applied to the program being developed in this study to select the lift equipments by the analytical process of domestic companies and lift load.

Relationship matrix analysis on the factors derived from previous studies was carried out to select the design influential factors for the development of the program to select the lift equipments for a high-rise building construction. The contents of this analysis are summarized in the following figure 3.

Relationship Matrix														
Strong 9 Moderate 3 Weak 1														
Function	Sensor installation					Equipment type by frame type		Lifecycle per each floor		Economic analysis				Weight for the analysis
	installation method	storage method	data type	ease of handling	ease of application	lift load	lift time	standard floor	standard floor + non-standard floor	marking of height limit	cost comparison	suggestion for alternative equipment	case comparison	
real-time measurement	④	③	③	○	△									5
application of actual data		○	○			○	④			④	○	○		3
application of construction speed for each floor								○	④	○		③	△	5
decision-making support										④	④	④	△	3
score	45	54	54	15	5	9	27	15	45	69	36	81	8	

Figure 2: Relationship matrix analysis for the selection of design influential factors

The result of this analysis is described as follows.

Firstly, with respect to real-time measurement for actual data collection, sensor installation method, storage method, and data type were significant.

Secondly, regarding actual data application, lift time and marking of height limit for the equipment scored the highest.

Thirdly, with respect to the speed of construction for each floor, frame construction cycle for each floor and the alternative equipment for economic analysis were important.

Lastly, as for decision-making support, items of economic analysis scored the highest.

Based on these results, analysis of Pugh matrix type by influential factors was

conducted, and the optimum design alternative was derived as shown in table 3 below.

Table II: Optimum concept design for the program development

classification	main function	design factors
actual data collection	information gathering	• installation of sensor operating seat
	storage method	• storage kit
	type of collected data	• number, type/time, lift weight, height/distance
method of data application	lift load	• lift load for each floor, packing method by the material type
	lift time	• machine speed, member (part) installation/time, actual data comparison, vertical movement distance
decision-making support	examination of target lift	• marking by each floor, 1 fall / 2 fall
	cost comparison	• monthly rental cost, cost for structure reinforcement, cost of installation removal
	proposal for alternative equipment	• equipment appropriate for the height and speed of construction

4. Evaluation of design influential factors

As described earlier, actual data collection, data application method, and decision-making support were selected as optimum concept design factors. These influential factors possess potential risk in the development process of the program to select the optimum lift equipment. Accordingly, there is a necessity for the process to reduce the risk beforehand by establishing the countermeasures after identifying the risk and its effect. Hence, FMEA (Failure Mode and Effect Analysis) should be performed to evaluate the potential risk and to establish the alternative for the risk reduction.

4.1 FMEA (Failure Mode and Effect Analysis)

FMEA is a method to evaluate the influence or consequence of the failure occurring in each element of the system process to the overall system. It can be

applied at the stage of process design. It can identify the potential defects in the design stage so that the cost and time can be reduced through the inspection of the products after the application of the system process (Stamatis, 1997).

FMEA has been used in manufacturing industry to identify the type of potential failures from the quality management perspective and to remove or reduce the factors for the occurrence of defects by its risk priority. Generally, It evaluates the occurrence, severity, and level of detection of the potential risk factors. Occurrence refers to the frequency of potential for defect, and severity refers to the level of influence to the detrimental result of the defect. Level of detection means the probability for the customer to detect the defect. Then, risk priority number (RPN) is computed by multiplying the scores of these three factors. It is the essence of this FMEA method to evaluate and identify the risk factor of focus. Thus, FMEA focuses on the critical few of highest risk priority to prevent the occurrence of failure and to minimize its effect (Pyzdek, 2003).

4.2 Potential risk analysis through FMEA

These advantages of FMEA can be expected in construction industry. Because the process of skyscraper construction is very repetitive compared to typical construction project, the construction process by each floor of a high-rise building is similar to the production process of manufacturing industry. If there occurs a failure in the lift plan, it will affect the overall construction very severely. Thus, if FMEA is used to identify potential risk factors in the planning stage of a construction project for the cost reduction priori, then the effect of potential failure can be greatly reduced. Figure 4 illustrates FMEA analysis based on the potential risks and their expected effects involved in the establishment of the program to select the lift equipment.

Process	Potential risk	Expected effect	Evaluation				Alternative
			occurrence	severity	detection	R P N	
actual data collection	sensor failure	lack of lift record by member	2	4	4	32	regular inspection (more than once a month)
	loss of storage data	loss of accumulated record	4	5	2	40	storage of daily work record in the server
	data reliability	storage of actual data usage record	5	5	4	100	deletion of erroneous data by weekly examination
data application	omission of lift material input	increase in the lift load	5	4	3	60	provision of member (part) list by frame type
	omission of lift time input	shortcoming of lift cycle prediction	4	5	3	60	separate input mode for equipment cost plus installation time
decision-making support	cost change due to the location of the equipment	increase in the cost by location	2	2	3	12	user-input program for the selection of the equipment location by the reinforcement type (in the future)
	deviation from the target construction	investment of excessive equipments	4	5	4	80	selection of equipments related to the construction process
	error in the lift cycle for each floor	error in the overall construction time	4	4	4	64	provision of input mode for the process table

occurrence
severity
detection

1 ~ 5

RPN Indicator

Red 100 or above
Orange 60 or above
Yellow 25 or above
Green below 25

Figure 4: FMEA analysis based on the potential risks

The result of the analysis indicates that the data reliability, deviation from the target construction, errors in the lift cycle for each floor, input errors of the lift material and lift time, etc. are important risk factors.

4.3 Process control system

A control process to reduce the risk factors was established based on the result of FMEA for actual data application, data application, and decision-making support. This is summarized in the following flow diagram for the space limitation.

The contents and important items of improvement over existing lift process plan are summarized below based on the contents of research described so far.

- Lift plan in high-rise building construction is a factor directly influencing the construction time and cost.
- Accurate analysis and prediction are possible through the application of actual construction data in comparison with

heuristic lift cycle selection method based on previous experience.

- The development of sensors for the gathering of real-time work data and its application are defined and documented.
- It is possible to predict and deal with the list of items related to lift in advance for the accomplishment of target construction time for each floor.

5. CONCLUSION

Finishing the frame construction in time is critical path in the overall construction process management for skyscraper construction. It is because the cost and time required for the frame construction accounts for 30~40% of total construction cost and time. Additionally, because movement of all materials and resources relies on tower crane or lift car in the skyscraper construction site, lift plan and frame construction are closely related. This study

derived the process/procedure for lift cycle prediction method to support the frame construction and the design concept for the development of lift cycle prediction. Although many researches on lift plan for materials and particular engineering methods are being carried out actively in general, the research on the prediction of lift cycle and the development of such a system has not reached the satisfactory level as of yet. Thus, this research will go on to develop such a prediction system based on the alternatives and findings of this study as well as actual construction data already collected.

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