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LIFT CYCLE PREDICTION METHOD FOR THE SELECTION OF LIFT EQUIPMENT IN SUPER TALL BUILDING CONSTRUCTION

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ABSTRACT : The demand for super tall building construction is increasing worldwide. There has been a constant request for achieving early payback on investment by shortening the construction time. This pertains especially for the case of huge investment projects such as super tall building construction. It is very important to shorten the construction time for the building framework, which requires substantial construction time and cost, and this is directly related to the establishment of an optimum lift plan for construction. When there is a problem in the selection of the lift equipment, it is almost impossible to revise the selection, resulting in a possible failure of the project. Thus, the purpose of this study is to analyze the function and logic for the development of the process for the selection of lift equipment for super tall building projects and further development of making the analyzed process into a system. In line with this research objective, the process of selecting the optimum lift equipment by domestic construction company was investigated and analyzed as well as collecting the actual field data. The actual data were obtained by sensors installed on tower cranes at three construction sites with the help from the construction company.

Keywords: ***influential factor ; lift equipment(T/C) ; process ; super tall building***

1. INTRODUCTION

Planning and management of lift is the most essential area of management of super tall building construction. It is the lift plan for the optimum management of materials to use tower cranes for vertical transportation of materials and human resources necessary for the construction. According to CTBUH(Council on Tall Buildings and Urban Habitat), 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 for super tall building projects is expected to be greater in the future. 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.
Thus, the purpose of this study is to analyze the function and logic for the development of the process for the selection of lift equipment for super tall building projects and further development of making the analyzed process into a system.
The concept diagram and flow of this research is illustrated in figure 1.
There are many factors to be considered for the establishment of construction plan for super tall building projects unlike regular construction projects.

Examples of such extra factors of consideration for super tall building projects include the construction time per each floor, form work, procurement of resources for construction. This study focused on lift equipment, especially tower crane(hereafter, T/C), for the vertical transportation of such resources. Lift equipments such as T/C and lift is the only means of vertical transportation of people and materials for super building construction projects. Thus, this study focused on finding out the method to make the selection of the location and number of T/C easier and intended to use the result of this study for the development of such a system. First of all, the process of selecting the appropriate T/C is investigated, and the function and logic necessary for the establishment of a system for the selection of lift equipment are analyzed.

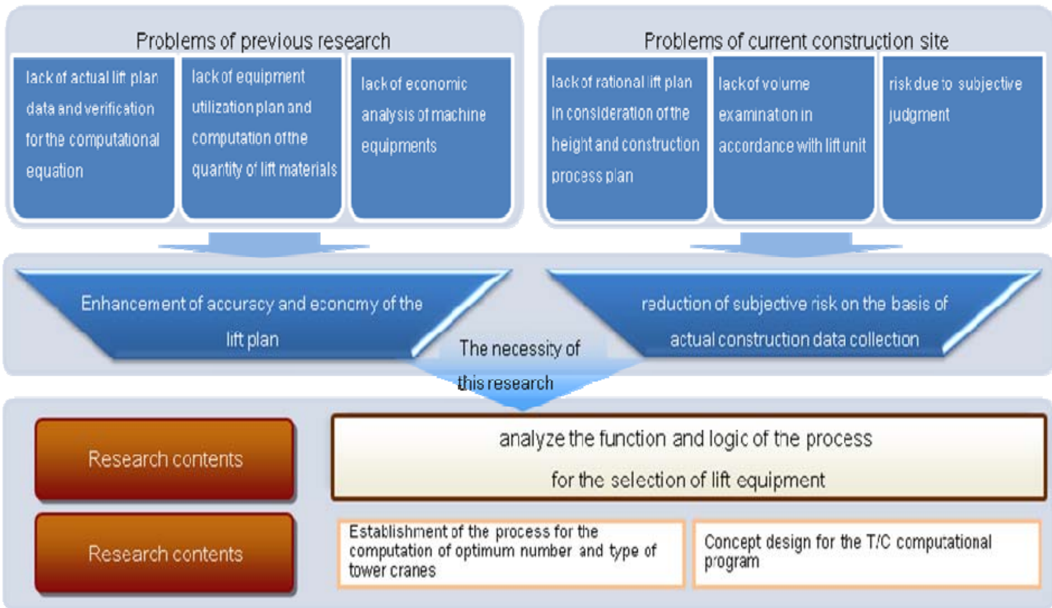

Figure 1. Concept diagram and flow of this research

2. PRELIMINARY ANALYSIS

2.1 Literature review

The existing researches related to the selection process of the crane for the lifting work have been reviewed, and the limitations are identified. The literature review is divided into the section on the selection of a crane appropriate for the lifting plan and the section on lifting plan system and its influential factors.

(1) Researches on the Selection of T/C for Super Tall Building Construction

Researches on the selection of T/C in relation to a lifting plan have been developed as follows.
Furusaka and Gray (1984) suggested a method to select the optimum crane, using an objective function to minimize the cost of renting, installation, and removal. Although they succeeded in suggesting an ideal model for compound assembly of various cranes, their research was not practical for the case of advantageous super high-rise building construction in terms of the construction period and cost, when the same crane is used continually. Additionally, their study did not adequately reflect the information on the number of cranes that can be used in the construction field site.

Gray and Little (1985) suggested a systematic approach to select mobile cranes and tower cranes appropriate for initial design stage. Especially, tower cranes of jib type and various base type were selected appropriate for the field conditions. Moreover, they suggested a systematic method to determine the location of those cranes for the field working condition. Nevertheless, they did not suggest the method to examine the safety of those selected cranes nor the method to use the information on various types of cranes. <Table 1> summarizes the contents of these researches and their limitations.

Table 1. Researches on T/C selection

researchers	year	content	limitation
Furusaka and Gray	1984	proposed an objective function of minimizing the cost of renting, installation, and removal to select the optimum crane .	lack of information on the crane appropriate for the field application
Gray and Little	1985	suggested a method of selecting the crane of choice based on crane specification to reflect the initial design requirements	lack of investigation on the safety of the crane of choice

		and field conditions.	
Kim, Hoon	2000	proposed a decision-making model to select the lifting equipment.	lack of applicability to field conditions

(2) Investigation of System Development and Influential Factors for Lifting Plan

Various researches on lifting equipments are being actively carried out recently. Examples of such studies include 'Evaluation of Time-Affecting Factors in High-Rise Building Construction' (Hong, Young T. et. al., 2004) and 'A Study on the Hoisting Planning System in High-rise Building Construction' (Kim, Jung J. et. al., 2005).

Table 2. Researches on influential factors for lifting plan

researchers	year	content	limitation
Hong, Y.T.et.al.	2004	proposed a method for evaluating the influential factors for the frame work construction duration, using FMEA (Failure Mode and Effect Analysis).	The investigation of the influential factors was strictly based on literature review, and its principal aim was to reduce the risk of delaying the project
Lee, J.R.et.al.	2004	derived uncertain factors during tower crane work and built a prediction model for the lifting time.	dealt with apartment buildings of medium height (15 floors or higher), which deviate from the interest of this research
Kim, J.J.et.al.	2005	developed a lifting plan system for super high-rise buildings in Korea (46~69 floor).	failed to consider the change in the lifting time with the height due to the lack of actual construction data.

Nevertheless, they are limited to the determination of number, lifting load, location, type of T/C except the equipment operation plan, or they dealt with the process of evaluating influential factors for the construction period at the planning stage. Thus, they have not dealt with the objective of this study, i.e. the prediction of the lifting cycle.

Additionally, the study of Lee, Jong R. et. al. (2004), entitled 'Models for Predicting Hoisting Times of T/C in the High-rise Building Construction', dealt with the steel-bar lifting of 17~18 floor apartment construction, deviating from the subject of this research, super high-rise building of 50 floors or higher.

2.2 Overview of the process for the selection of lift equipments

The reason for the importance of tower crane in super tall building projects is because there are many variables of influence to super tall building projects in comparison to ordinary construction field projects. The selection of required tower cranes is conducted generally by the following order(Figure 2).

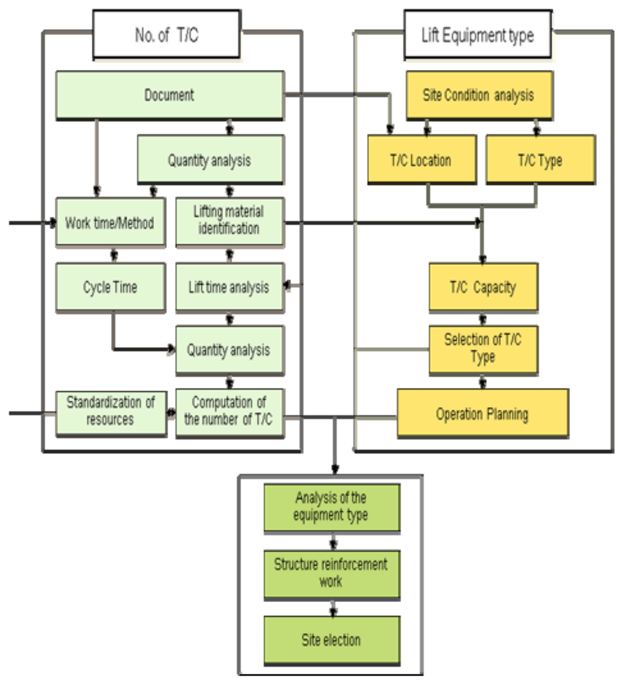

Figure 2. General process for the selection of lift equipments

There are additional facts to be considered in this process. The detailed analysis diagram for the computation the number of required T/C is illustrated in figure

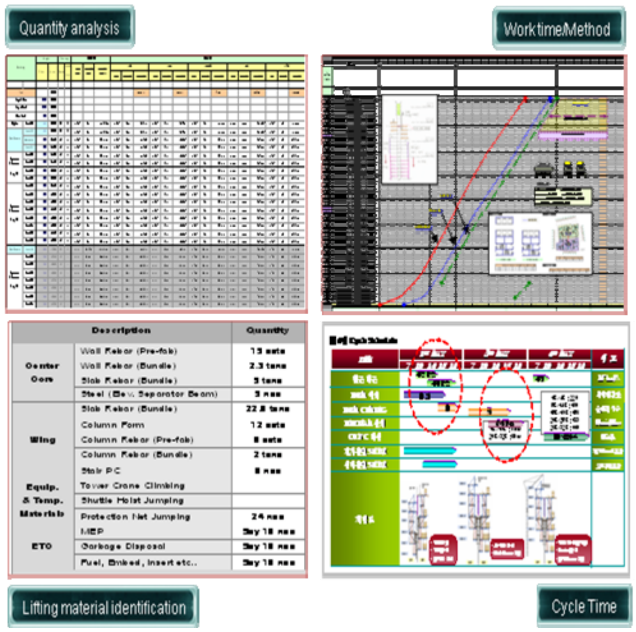

Figure 3. The detailed analysis diagram for the computation the number of required T/C

The detailed analysis diagram for the selection of required T/C type is illustrated in figure 4.

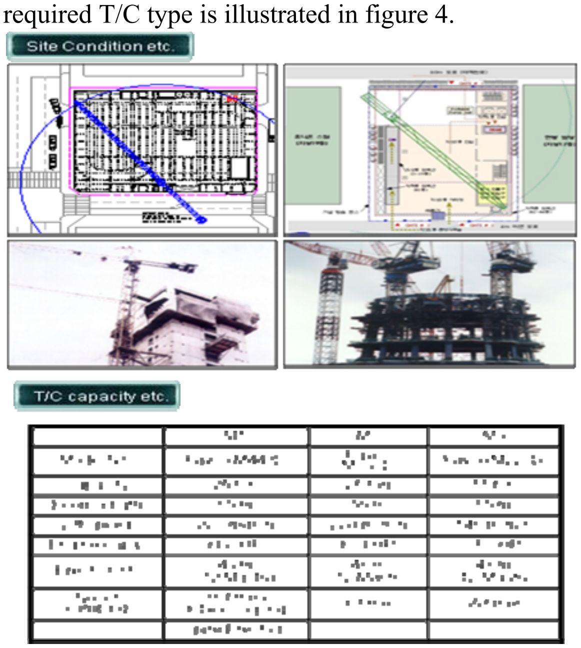

Figure 4. The detailed analysis diagram for the selection of required T/C type

Since lift cycle time includes lift time and installation time, the process of computing the number of required tower cranes must consider horizontal movement distance and vertical movement distance. The mechanical limit speed is important at this time. Additionally, because there can be deviation of data due to the human factor (the capability of the T/C operator and the site condition), sensors were attached to collect the actual data. Figure 5 shows the concept diagram for the process and development of the program to compute the number of required tower cranes.

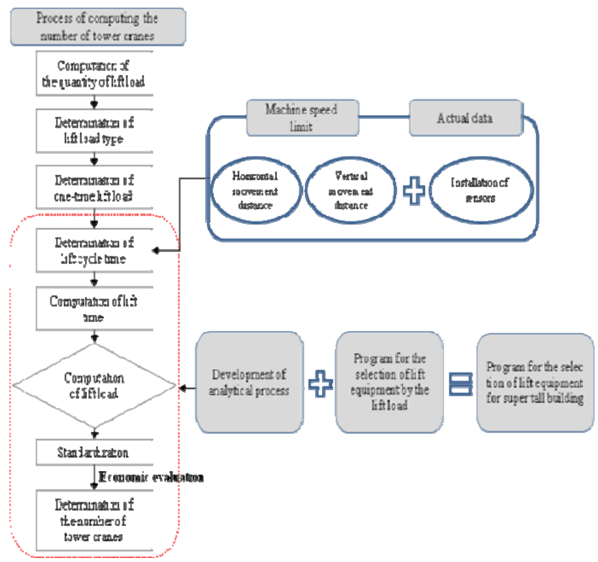

Figure 5. Concept diagram for the process and development of the program to compute the number of required T/C

3. Analyses of the Selection Process for Lifting Equipments and Its Influential Factors

3.1 Cases analyzed

Generally, super tall buildings refer to over 50 floors and over 200m in height. The recent building projects are much larger in size than this conventional definition. There are many cases of super tall building projects in Middle East, China, and Southeast Asia scaling at over 100 floors and over 500m in height. This study limited its scope to the selection of tower cranes for RC type frame construction. The reason is because domestic RC type frame construction does not have a competitive edge over foreign companies, although domestic technology on SRC type frame construction is very competitive to foreign technology. According to recent data, the average operation percentage of T/C for SRC type frame construction and RC type frame construction was 73.5% and 49.5%, respectively. Accordingly, the RC type frame construction was selected for the focus of this research for its lower operation percentage and large room for improvement.

Table 3. Ratio of lifting work for each material by different frame types

Frame type	Ratio of Lifting Work by the Material (%)				
	Steel Frame	Rebar	Form	Miscellaneous	Total
SRC	52	19	8	21	100
RC	0	41	49	10	100

3.2 Analyses of the Selection Process for Lift Equipments and Its Influential Factors

Figure 6 illustrates the planning process for the selection of lifting equipments for super tall building construction. Although the ultimate goal is the establishment of a system for the selection of lifting equipments for super tall building construction projects, this study limits its scope to the process of selecting optimum lift equipments for the analysis and establishment of a system from its function and logic perspective. Based on the process illustrated in figure 6, the potential influential factors are classified to select the optimum lifting equipment by the lift load.

Figure 6 illustrates the planning process for the selection of lift equipments for super tall building construction, which many construction companies involved in the super tall building construction should consider. Each influential factor affects the process of selecting optimum lift equipments by the project condition at each stage of the process.

Thus, the procedure to select potential influential factors of ordinary content and to make them materialized is needed. (cf Table 4)

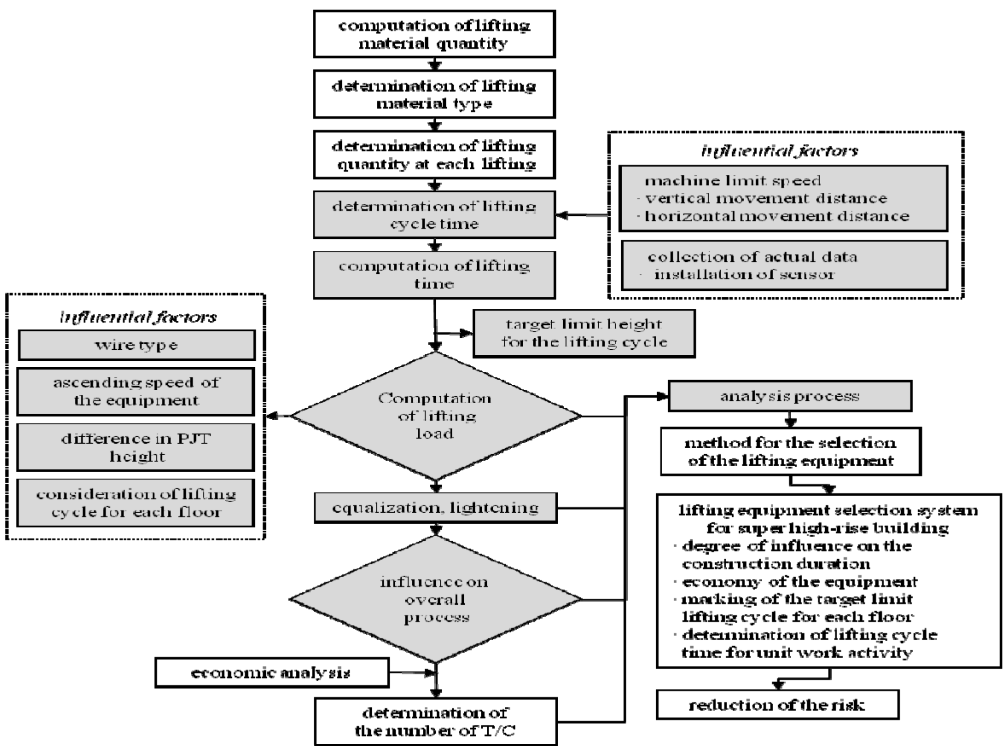

Figure 6. Planning process for the selection of lift equipment

Table 4. Potential influential factors for lifting plan

classification	lifting process plan	potential influential factor
computation of lift load and stage for the determination of the number of T/C	lifting material quantity	structural type, engineering method, building height
	lifting quantity at each lifting	equipment capacity, lifting material size, lifting material weight, equipment
	number of lifting	equipment capacity, material resource quantity, engineering method, packing method, equipment speed
	time for one lifting cycle time	time to bind the material, time to unbind the material, building height, experience of the operator, pulling speed of the equipment, engineering method
	computation of lifting load	actual operation time ratio of the equipment, frame cycle, number of T/C, daily time required for lifting
stage for the determination of T/C location and type	number of lifting equipments	Building shape, daily operation ratio, construction schedule, building plan
	determination of lifting location	installation location of the member, maximum weight of the member, interference, building shape, installation space for the member, radius of T/C, stock yard location, method of removing the equipment
	determination of lifting specification	maximum weight of the member, radius of T/C, speed of T/C, surrounding condition, length of jib, building height, pulling weight of the equipment, stock yard location
	selection of the lifting equipment type	performance, economy, safety, usage time, repair/maintenance status, easiness of control, convenience of parts procurement

4. Analysis of function and logic for the selection of optimum tower crane

First of all, the process of selecting the optimum tower cranes for super tall building projects such as collection of actual data, application of the data, decision-making support, etc. was delineated. Then, the function and logic for the development of the system for the selection of optimum tower cranes were analyzed, and the method for the application of the results of this study to the development of such a system was investigated.

4.1 Detailed analysis of the process for the selection of optimum tower cranes

(1) Process of collecting actual data

The process of collecting the actual data is largely divided into three time periods, i.e. preparation for lift work, lift work, and after lift work. This study collected the data from two domestic construction sites and one overseas construction field site. Sensors were attached to tower cranes at the field sites of super tall building construction for actual data collection. The detailed procedure for the collection of actual data is depicted in figure 7.

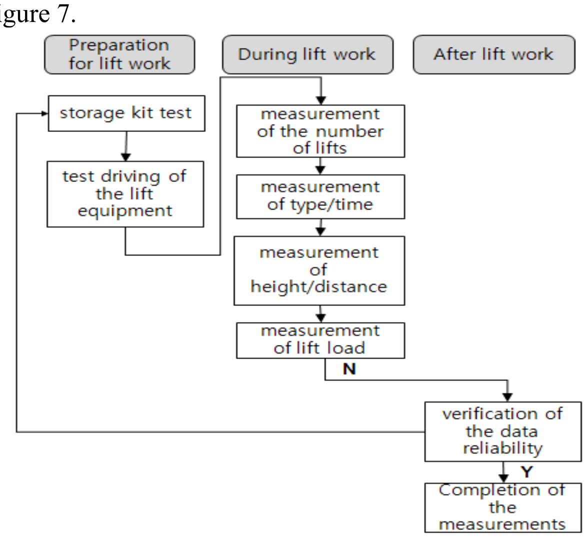

Figure 6. Process of collecting actual data

(2) Process of applying the data

The process of applying the actual collected data involves three stages of inputting fundamental data, analyzing, and selecting the potential tower crane for lift work. The fundamental input data are lifting materials, target lift cycle, daily working hours, and work time by each task. These data are selected based on the analysis of influential factors previously discussed, for the lift plan is very closely related to the overall construction plan.

The detailed process of applying the actual data is depicted in figure 8 below.

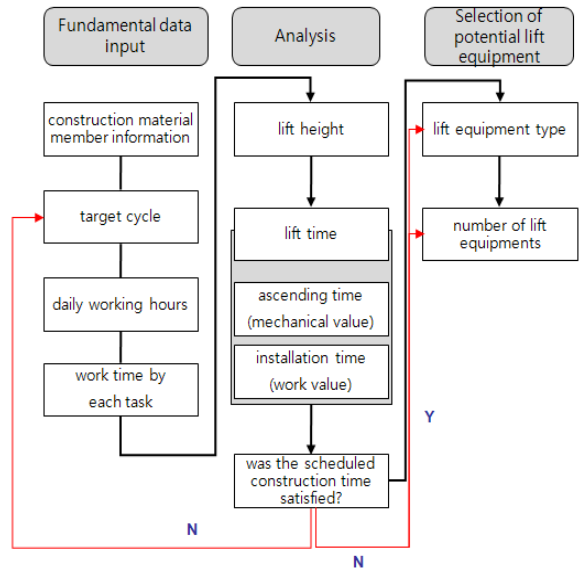

Figure 7. Process of applying the actual collected data

(3) Process of decision-making support

Various influential factors must be considered in the decision-making for the selection of lift equipments appropriate for the project. This study prepared such a decision-making process by three categories, i.e. expected risks, analysis, and product.

Figure 9 illustrates detailed process of decision-making support. The construction time delay by the floor among expected risks should be controlled and related to the construction task management. Although the increase in the number of equipments and upgrade of the equipment type should occur infrequently, its severity of influence is very large. Thus, a thorough analysis should be performed beforehand so that these types of risks would not occur.

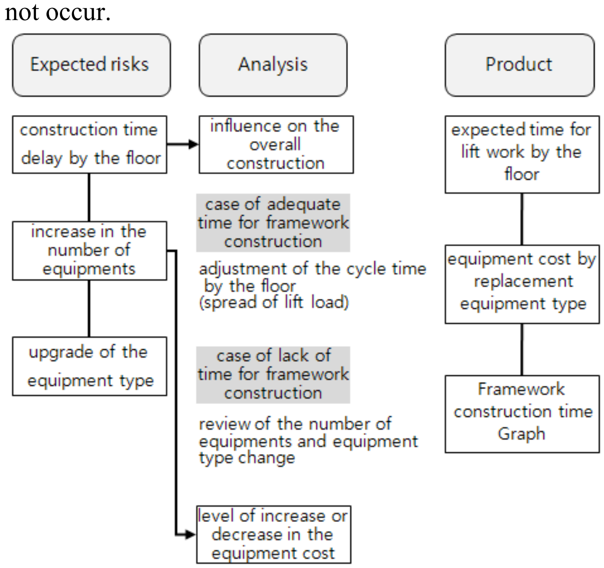

Figure 8. Process of decision-making support

4.2 Application process for the development of a system for selecting the optimum lift equipments

It is the final objective of this research to develop an automated system for the selection of optimum lift equipments, and the scope of this research is limited to preparing the algorithm of the process that can be applied to this system. The system for the selection of lift equipment consists of the stage of inputting the fundamental data collected from the field site, the stage of inputting and analyzing the lifting materials, the stage of inputting and analyzing the construction time, and finally the stage of selecting the optimum tower crane. The detailed application process for the development of a system for selecting the optimum lift equipments is depicted in figure 10.

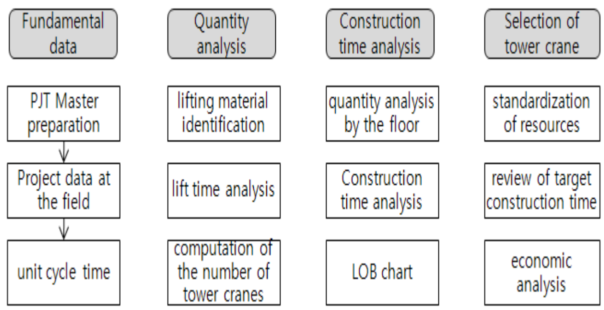

Figure 9. Application process for a lift equipment selection system

5. CONCLUSIONS

Completion of frame construction work is the critical path in overall project schedule management for the case of super tall building construction. It is because the cost and time for frame construction work takes about 30~40% of entire construction project. Additionally, since all movement of materials and resources relies on T/C and lift car, frame construction work and lift plan are closely related. This study analyzed the process of selecting optimum lift equipments for super tall building projects and derived its related influential factors. Additionally, the function and logic at each stage of the development of an automated system for the selection of optimum lift equipments were analyzed in order to build the framework for such a system.

It is our future research agenda to develop a computerized system to select the location and the number of lifting equipments in consideration of the lift load and construction period (duration) after an objective verification of the influential factors proposed in this study.

Although investigations of lift plan with respect to the lifting material and particular engineering methods are being pursued actively, the research on the development of a computerized system for the prediction of lift cycle has not reached the satisfactory level yet. This research will continue with the collection and analysis of data related to lift plan in order to build the aforementioned system based on the alternatives as suggested in this study.

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