AN OPTIMATL ALGORITHM OF THE MULTI-LIFTING OPERATION FOR SUPER-TALL BUILDING

Chang-Yeon Cho[1],Yoonseok Shin[2]*, Moon-Young Cho[1], and Seo-Kyung Won[1]

[1] *Construction Management & Economy Division, Korea Institute of Construction Technology, Goyang, Korea*
[2] *Department of Architectural Engineering, Gyeongnam National University of Science & Technology, Jinju, Korea*
** Corresponding author (ysshin@gntech.ac.kr)*

ABSTRACT: The operation and management plan for a lift, an important factor determining work productivity on a high-rise building construction site, has long been considered to be less significant than those for a tower crane, which has resulted in a lack of studies of systematic operation planning for lift. Due to various restrictions on high-rise construction sites, only a small number of lifts can be installed. The restrictions on the installation of lifts have a great influence on labor productivity by floor, which can be changed by the management of the vertical movement of the lifts. Improving the work efficiency of lifts at a construction site is evaluated as an essential management factor to improve labor efficiency on each floor; on the other hand, the efficient management of such lifts is dependent on experienced workers. Considering this, as part of a simulation development for the work efficiency of lifts, one of the major factors in a high-rise building construction, this research aims to develop an algorithm to predict and operate the optimal lift operation time, when two or more lifts are simultaneously operated, based on the work efficiency time calculation algorithm, and to present the optimal operation expectation of the lift in a quantitative way. In the future, the algorithm developed in this research will be equipped in a module to predict and evaluate the work efficiency of a lift in an intelligent work efficiency management system.

Keywords: *Optimal Algorithm, Multi-Lift Operating, Super Tall Building Construction, Construction Lift*

1. INTRODUCTION

The construction lift in super high-rise building can be installed with limited units due to various restricted conditions and the restrictions caused by these characteristics of construction lift have a close effect on the each floor-specific labor productivity changing by vertical circulation.Accordingly, the operation management of lift in the super high-rise building could be the critical factor to decide work productivity on the spot [1].

In case of the current lift operation plan in the super high-rise construction, the plan and operation are dependent on the experienced engineers from related companies based on the construction company-specific different criteria [2], but it is hard to objectify the experiences of the skilled engineers because they have different experiences, so in order to solve those problems the hoisting plans are been establishing with using the margin of operation rate.

On the spot of super high-rise construction such as urban construction limited in terms of the open air storage, however, various approaches are been tried to raise the operation rate, but it appears very difficult to identify the method to utilize the quantitative indicators, the one to raise the qualitative indicators such as the operation rate dependent on the experiences of skilled engineers.

Accordingly, this Study, as a part of simulation development of hoisting management as a critical operation factor in super high-rise construction, purposed to present the optimal operation plan algorithm to quantitatively raise the lift operation rate in time of locating two or more construction lifts on the spot utilizing the time calculation algorithm for hoisting plan with considering adjustable speed function of the existing developed construction lift, and then to present a method for a quantitative, systematic lift hoisting operation with utilizing and validating the simulation technique from the presented algorism.

2. CONTRUCTION LIFT OPERATION TIME CALCULATION ALGORITHM

As demonstrated in previous studies, cycle time for lifting(T) was defined as follow Formula 1(Cho, Kwon et al, 2009). Tm indicates lifting time of a hoist, and Tl means loading/unloading time of resources such as workers and construction materials [3].

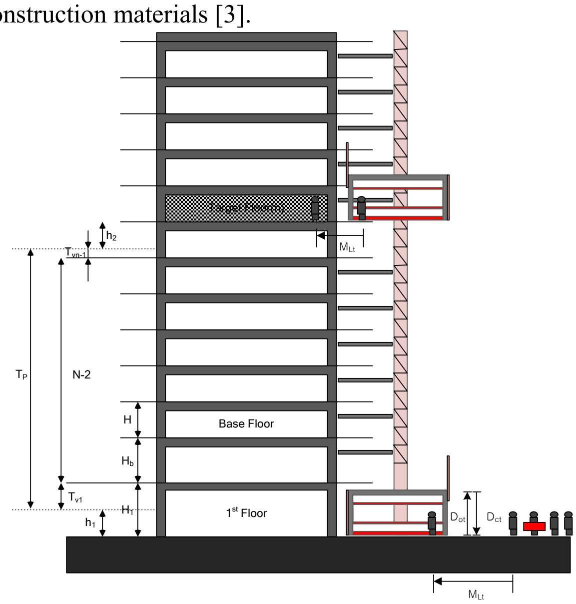


Figure 1. L/C Operating Time Calculation Model

H:Height of typical floor

H_b:Each height from ground floor to typical one

a:Acceleration reaching operation speed

a':Deceleration reaching stop

h_1:Distance required to reach operation speed

h_2 :Distance required to reach stop speed

s_1:Time needed to acceleration

s_2:Time needed to deceleration

n:Number of stop floors

m:Number of passing floors

Lift operation time (T1) calculation:$T_L = T_m + L_t$

Lift movement time (Tm) calculation:$T_m = T_p + S_1 + S_2$

Total time needed to reach safety operation speed (T_p) calculation:

$$T_p = T_v + T_{v1} + T_{vm-1}$$

$$T_v = \frac{\sum_{i=2}^{n-2} H_i}{V},\ T_{v1} = \frac{H_1 - h_1}{V},\ T_{vm-1} = \frac{H_{n-1} - h_2}{V}$$

Time calculation of loading/uploading of hoisting resources:

$$L_t = (D_{ot} + D_{ct} + M_{lt}) \times 2$$

3. MODEL FOR METHOD TO OPERATE TWO OR MORE LIFTS

3.1. Model setting

Of lift movement forms on the construction spot, this Study analyzed largely the following two types:

1) In case of hoisting persons at multiple floors starting from ground floor with multiple hoists; and
2) In case of receiving calls from lifts at multiple floors when multiple lifts are waiting at different floors

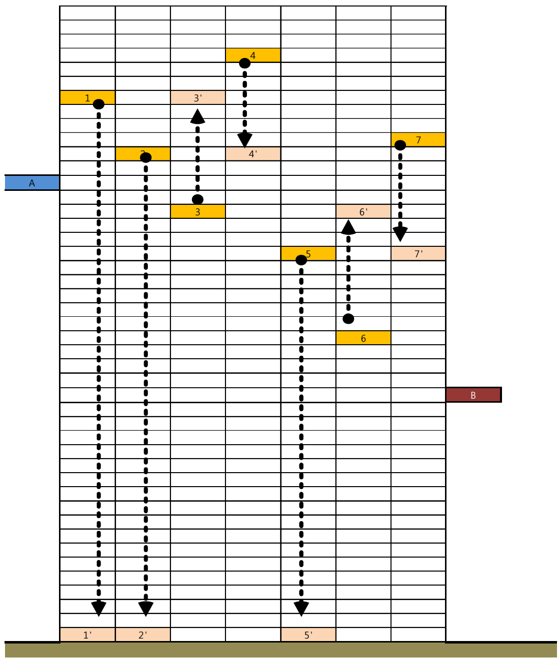


Figure 2. .A model for research

In case of the above 1) corresponding to the peak rush hour at lift circulation, generally the hoists of n units are operated and in case of the m-story building, the proportional route plan would be optimal.

In case of the above 2) corresponding to the general working hours to hoist materials and persons at the same time after rush hour, a simulation is needed to level the hoisted materials for an efficient process plan and a finishing work would generally be most problematic.

This Study focused on developing an optimal route plan algorithm corresponding to the above 2) case, so the diagram of the research model is same as Figure 2.

That is, the optimal operation method is defined as a method to have minimum time when the lifts of n units starting from No.m_a floor hoist multiple persons at a m_n–story building and the optimal route plan method is defined as an optimal operation algorithm.On the other words, the modeling of this Study's targets can be defined as follows:

Number of hoists:'n' units
Number of movable floors:m_n
Inter-floor travel distance L_m
Total travel distance:$\sum L_m$

3.2Traveling Salesman Problem(TSP)

As described at Section 3.1, the production of optimal travel route for hoisting persons from ground floor to No.m floor using the lifts of n units has the similar characteristic with a traveling salesman problem (TSP).

TSP is defined as a problem to seek an optimal travel route for one salesman to pass all the points of n units, so the route plans increase to m!whenever the points increase by m units [4].

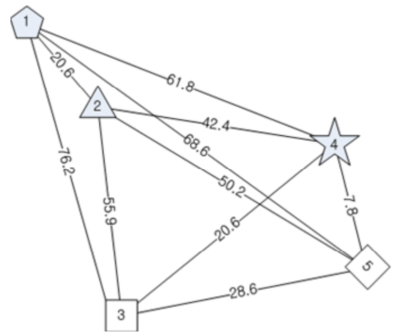


Figure 3. Typical Traveling Salesman Problem

That is, in case a graph of TSP is given and the weight to each side (including length) is defined, it means the problem to seek a route to make the total of weights minimized through passing all the points of this graph, so the problem belongs to NP-complete problem.

NP-complete problem is a problem of P≠NP; P means a problem belonging to P (Class P) and NP means a problem belonging to NP (Class NP).

Class P means problems to be solved to make an efficient operation possible through using any algorithm within polynomial time and the problems belonging to Class NP mean problems to be solved within polynomial time using non-deterministic algorithm [5].

The lift travel route plan, a target of this Study, can also be said to be a problem related to that TSP.

3.3 Branch and Bound Algorithm(B&B Algorithm)

There are various algorithms to solve TSP belonging to NP-completed problem, but the branch and bound algorithm is representative out of algorithms used to solve the optimization problem.B&B algorithm is used to seek the maximum or minimum problem of TSP.

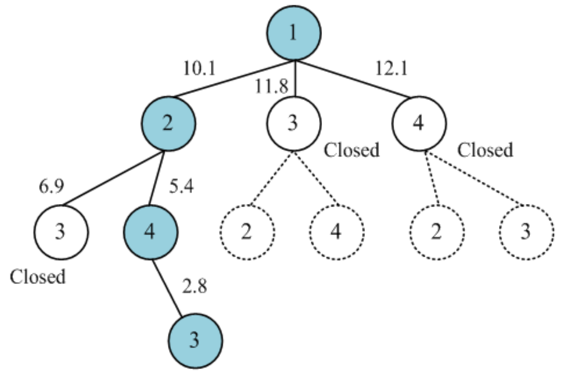


Figure 4. Example of Typical B&B Algorithm

B&B of TSP was first presented at a thesis of Dantzig, Fullkerson and Johnson in 1954, and the term of 'branch and bound' was first used at a thesis of Little, Murty, Sweeney & Karel in 1963 [6]. According to a B&B method, problems are divided into smaller sets and then the bound of object function in each sub-set is calculated.On the other words, the bound of the given problems is calculated until easily seeking the solution through repeating a process to make the bound smaller or easier [7].

Like the above Figure 4, B&B is a method to reduce the number of nominations to be considered with using the bound of each node.Because each node is disassembled again, the disassembly operation can largely be shown as wood structure.When disassembled as a part problem, it is a method to seek the reduction of case number through limiting branch against the part problem not to be able to grant the optimized solution to original problem using the upper/lower limit of local optimization..(Kim et Al., 2005)

4 OPTIMAL OPREATION ALGORITHM OF CONSTRUCTION LIFT

4.1 Simulation Condition and Model

The simulation conditions conducted in this Study are assumed as follows:

First, all the floor heights from ground floor to No.m_a floor are assumed to be same.

Second, all the construction lifts travel only one floor per one time travel, and then they move to another floor after reaching the destination.

Third, at the floor where one construction lift reach, the other construction lifts don't run.That is, all resources of one floor per one-time construction operation move.

Fourth, all the hardware specifications of the construction lifts of n units are same:rise/fall speed of 100m/min, acceleration capacity of 0.60m/sec^2 and deceleration speed of 0.57m/sec^2.

Fifth, all the construction lifts of n units start the operation at the same time.

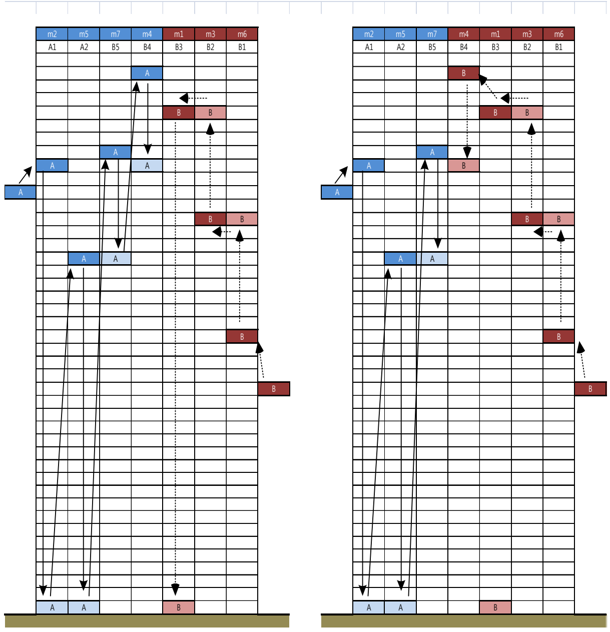
Sixth, the optimal travel route in the construction lifts of n units means the route to make minimized the required time from start to finish.

Under this condition, this Section tries to identify the feasibility and condition for B&B algorithm adaptability in time of operation plan for multiple construction lifts through the simulation of two construction lifts (n=2) in Figure 2.

4.2 Simulation of Multi-Lift Operating Optimization using B&B Algorithm

Based on the conditions of 4.1, a simulation was conducted for a case of resources movement through two construction lifts in the situation of Figure 2.

At this time, a simulation to incorporate B&B was conducted without considering the location change caused by movement time and a simulation to incorporate B&B was conducted considering lift time and location change; the results are as the following Figure 5.



1) B&B Algorithm without lift moving time concerned   2) B&B Algorithm with lift moving time concerned

Figure 5. Simulation Results

Under the above Figure 5, there was not a big difference between 1) and 2) and it's shown to grant same path to Lift A and B, but there is any difference between the calculation results about total travel distance with and without considering the time and location of lifts.

In case of 1), the path of Lift A took the total of 352.0 seconds to move all the resources of 4 floors, m2->m5->m7->m4, and Lift B 135.2 seconds to move all the resources of 3 floors, m6->m3->m1.

In case of 2), there was only difference for m4 to move from Lift A to B on the path of Lift A and B, but there was some difference in time:306.4 for Lift A and 231.0 seconds for Lift B.In next section, the difference occurrence in the results of the simulations conducted at this Section will be analyzed.

4.3 Simulation Result Analysis

The results of the simulations conducted at this Study are as the following Table 1.

Simplified B&B Result								Total Operating Time & Bound	
Branch 1	m1	m2	m3	m4	m5	m6	m7	Bound 1	Time
A	15.4	7.1	7.1	21.7	13.3	25.9	9.2	m2	81.2
B	46.9	38.5	30.1	53.2	23.8	11.3	40.6	m6	33.0
Branch 2	m1	m3	m4	m5	m7			Bound 2	Time
A	52.3	42.2	56.0	38.5	48.5			m2, m5	179.1
B	14.6	0.0	18.4	8.3	10.9			m6, m3	52.7
Branch 3	m1	m4	m7					Bound 3	Time
A	82.5	88.8	76.2					m2m m5, m7	275.0
B	0.0	9.2	9.2					m6, m3, m1	135.2
Branch 4	m4							Bound 4	Time
A	59.5							m2, m5m m7, m4	352.0
B	25.9							m6, m3, m1	135.2
Time Concernd B&B Result								Total Operating Time & Bound	
Branch 1	m1	m2	m3	m4	m5	m6	m7	Bound 1	Time
A	15.4	7.1	7.1	21.7	13.3	25.9	9.2	m2	81.2
B	46.9	38.5	30.1	53.2	23.8	11.3	40.6	m6	33.0
Branch 2	m1	m3	m4	m5	m7			Bound 2	Time
A	82.5	65.7	88.8	59.5	76.2			m2	81.2
B	19.6	0.0	25.9	9.2	13.3			m6, m3	52.7
Branch 3	m1	m4	m5	m7				Bound 3	Time
A	82.5	88.8	59.5	76.2				m2	81.2
B	0.0	9.2	25.9	9.2				m6, m3, m1	135.2
Branch 4	m4	m5	m7					Bound 4	Time
A	88.8	59.5	76.2					m2, m5	200.1
B	9.2	25.9	9.2					m6, m3, m1	135.2
Branch 5	m4	m7						Bound 5	Time
A	88.8	76.2						m2, m5	200.1
B	88.8	76.2						m6, m3, m1, m7	231.0
Branch 6	m4							Bound 6	Time
A	88.8							m2, m5, m4	306.4
B	15.4							m6 ,m3, m1, m7	231.0

Table 1. Difference between twosimulations

As shown at Table 1, if not considering on lift time and location, B&B operation of 4 times was identified as the required time of 352.0 seconds for Lift A and 135.2 seconds for Lift B, but if considering on time and location, 306.4 seconds for Lift A and 231.0 seconds for Lift B.

That's because the distance matrix among Lift A, Lift B and m_a is manufactured newly in order to deliver the next branch when setting the bound after delivering each branch if considering on required time and location.

In addition, this gap occurs because the related lift delivers a next branch and conducts the sequence to set bound newly when one lift of two ones is moving to the destination floor and the other is stopped.

5. CONCLUSION AND FURTHER STUDY

This Study verified the applicability of B&B algorithm for planning an optimal path in case two or more construction lifts are running and calls occur at multiple floors at the same time, which can be seen to be a changed TSP corresponding to NP-complete problem.

As a result of this Study through simulations, it was verified that the optimal path plan for multiple lifts is possible through applying B&B algorithm.

The optimal path for multiple lifts, however, should consider the location of related lifts and the required time occurring from movement between floors and perform the continuous branch setting and bound modification, so the resulting operation optimization of multi-construction lifts can be more accurate and efficient.

Accordingly, the future studies should research on B&B improvement algorithm to make an efficient operation plan possible in time of more various condition changes and lift unit changes and subsequently they will develop the efficient construction lift simulations.

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