

A Study on Optimal Operation Method based on Analysis of Lifting Time

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ABSTRACT

Boosted by the tendency becoming higher, larger and complex in Korean construction industry, the scale of workers and material has been increasingly growing. However, in most of construction sites, excluding some high-rise building construction, lifting work heavily depends on operator's experimental or intuitional factors, which often causes inefficient work that results in increase in cost and schedule. This study was intended to establish the measure to secure the productivity and economical competitiveness in Korea's construction project which has been getting larger and higher. To that end, analysis of the required time per cycle for manpower transporting and material lifting, focusing on lift among various lifting equipments, was carried out. Based on analysis result, optimal operation method which the study was aimed at eventually developing, is expected to be set up.

Keywords: Lift, Lifting Plan, Schedule Reduction

1. INTRODUCTION

1.1 Background and Purpose of the Study

Recently, construction projects in Korea have been getting higher, larger and complex, resulting in increase in number of workers and volume of material. Lifting plan, among others, at high-rise building projects is the critical factor in overall construction plan. However, in most of construction sites, excluding some high-rise buildings, lifting work heavily depends on operator's experimental or intuitional factors, rather than abiding by the established systematic procedure. Inappropriate lifting plan often leads to inefficient process, thereby eventually resulting in increase in cost and

schedule. That is, efficient lifting plan can bring about the reduction in cost and schedule. Generally, lifting equipment for high-rise buildings includes tower crane, lift and concrete pouring equipment. Lift, among these, is used to transport the manpower and small material, which is most commonly used among those three types of lifting equipment. However, the studies relating to lifting equipments were found to be mostly about tower crane, while those for lift still remain far behind, according to the recent survey. This study hence was eventually aimed at coming up with the effective measure to secure the productivity and economic feasibility at the construction sites becoming larger and higher.

1.2 Scope and Method of the Study

This study was limited to 30-story or higher apartment building construction sites, which have been in progress in Korea. And as indicated in <Fig 1>, lifting equipment is limited to lift that functions to transport the manpower and material, rather than tower crane, and the analysis of a single cycle time referring to the time taken to travel from the top to the bottom by the lift was made.

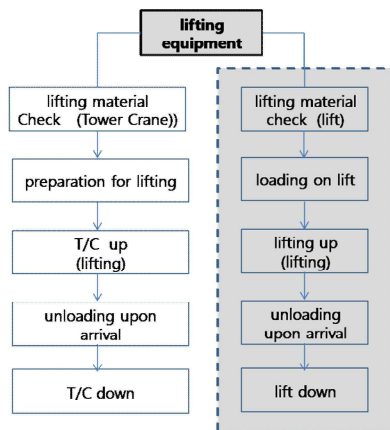


Figure 1: Scope of the Study

As shown in <Fig 2>, the working ratio at the normal apartment construction sites was examined before analyzing a single cycle time taken to travel from the top to the bottom. Based on analysis, a combined lifting time for manpower and material was compared to daily/annual lift working rate to identify the optimal lift operation pattern. To that end, the lift was categorized into high speed, medium speed and low speed and the time taken per cycle was also categorized into manpower transporting and material lifting.

2. THEORETICAL REVIEW

2.1 Definition of Construction Lift

According to the Article 100-1, the Regulation for Industrial Safety Standard, the construction lift shall be the machinery equipment designed to transport the person or cargo using a power and the construction lift shall be the equipment with motorized transport means moving vertically along the guide rail or those with a similar structure and function which was designed to be used at the construction site. That is, the purpose of using a lift at construction site is to transport the manpower as well as to lift the material.

2.2 Case Study

In an effort to identify the problems with lifting plan and previous studies, examination of relevant documents was conducted. As indicated in <Table 1>, no study was conducted since 2004 and no significant studies were found even before 2004. Chung Yong-chan (2004) and Kim Dong-jin (2002) pointed out in their papers insufficient records on lifting plan, unsystematic lifting plan and the lack of work analysis. though Kim Dong-jin (2002) proposed to work out the lifting plan based on frequency of lifting by type of material and activity, he failed to present the specific measure. But in this study, an optimal combination of manpower transport and material lift was proposed by presenting a specific data, thereby seeking the way of reducing the schedule.

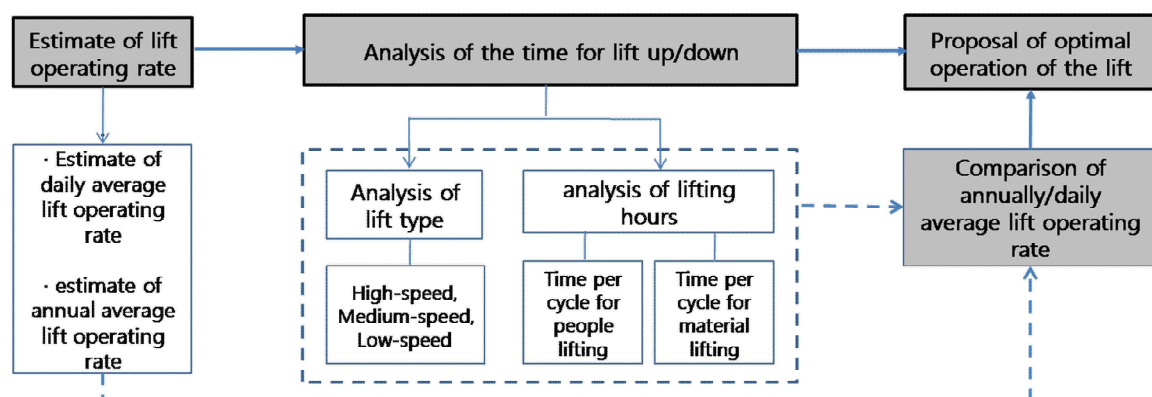


Figure 2: Research Flow

Table 1: lift-related Case Study

Researcher	Highlights	Problems
Chung et al (2004)	Identified the problems with lifting plan and influential factors using correlation analysis to present the quantity estimate system for lifting plan	No specific measure on quantity estimate was proposed, resulting in inefficient way for schedule reduction
Choi et al (2002)	Proposed the measure for improvement from institutional, technical and constructional aspect	Focused on safety of construction lift but has little thing to do with schedule reduction
Kim et al (2002)	Identified the problems with lift plan and proposed to set up the plan based on lifting frequency by type of material and activity	No specific measure for lifting plan and schedule reduction was presented.

3. ANALYSIS OF LIFT WORKING RATIO AND DAILY OPERATION HOURS

3.1 Estimate of Annual Lift Working Ratio at Site S

<Table2> indicates the annual lift working ratio at site S. Average equipment operation rate was estimated throughout the year, excluding non-working days affected by climate and holidays. The base of non-working days calculated is as follow.

- 1) When temperature is below 0°C, it shall be regarded non-working days for concrete work
- 2) When rainfall a day is 10mm or more, it shall be regarded non-working days for outdoor painting work.
- 3) When snowfall a day is 10mm or more, it

shall be regarded non-working days for roof waterproof work

- 4) When a velocity is 10m/sec or more, it shall be regarded non-working days for steel frame fabrication work.

Lifting for concrete work was not considered in this study and thus rainfall, snowfall and velocity shall be regarded as non-working days. Annual average lift operation rate after excluding the non-working days (non-working days + holidays) from the total annual working days was estimated at 71.77%.

3.2 Average Daily Equipment Operating Rate at Site S

Average daily equipment operation rate at Site S was estimated on assumption that the work starts 07:00 till 18:00 as indicated in

Table 2: Estimate of annual lift operation rate at Site S (2005.01.01~2005.12.31)

Month Item	1	2	3	4	5	6	7	8	9	10	11	12	Total
when rainfall is 10mm or more	0	1	1	2	2	1	5	5	1	0	1	0	19
when velocity is 10m/sec or more	0	2	0	2	1	2	1	2	1	0	0	1	12
when snowfall is 10mm or more	1	0	2	0	0	0	0	0	0	0	0	0	3
Holidays	6	7	5	5	6	5	5	5	6	6	4	4	64
Total annual days	31	28	31	30	31	30	31	31	30	31	30	31	365
Nonworking days	7	10	8	9	9	8	11	12	8	6	5	5	98
Actual work days	24	18	23	21	22	22	20	19	22	25	25	26	267
Working ratio(%)	77.4	64.2	74.2	70.0	71.0	73.3	64.5	61.3	73.3	80.6	83.3	83.9	71.7
Average (%)	Monthly Sum / 12 = 71.77(%)												

Table 3: Average daily operation rate of lift

Hours	Time (minutes)	Work description	Actual working hours (assumed 100%)
07:00~08:00	60	Safety meeting, work instruction, movement	0
08:00~09:30	90	Morning work	90
09:30~10:00	30	Morning coffee break	0
10:00~12:00	120	Morning work	120
12:00~13:00	60	Lunch break	0
13:00~15:00	150	Afternoon work	150
15:00~16:00	30	Afternoon coffee break	0
16:00~18:00	120	Afternoon work	120
Total	660 min (11 hours)	Actual operation rate: 72.7%	480 min (8hours)

<Table 3> (based on wintertime). Safety meeting at 07:00~08:00, 60 minutes for work instruction and movement to work site, 30 minute coffee break twice a day (morning/afternoon) and lunch break for 60 minutes. Hence, a lift efficiency is assumed to be 100%, actual operation rate (total hours/actual working hours) is 72.7%. The efficiency of the lift was assumed to be 100% for comparison in objective manner.

To be able to analyze the up-down travel time of lift, rating load, operation speed and capacity shall be identified. In this study, the time per cycle for manpower transport and material lift was calculated based on data identified, and compared with a daily average actual operation rate that combined daily actual operation rate indicated in <Table 3> and the cycle time for transport and lift. Based on analysis data, an optimal lift operation measure was eventually developed.

4. ANALYSIS OF LIFT OPERATION HOURS

Table 4: Analysis of lift by model

Category	H-speed L	M-speed L	M-speed M	L-speed L	L-speed M	L-speed S
rating load	3000kg	1500kg	2000kg	2300kg	2300kg	1200kg
speed	0~100m/min	0~60m/min	0~60m/min	0~40m/min	0~40m/min	0~40m/min
control	inverter (VFC)	inverter (VFC)	inverter (VFC)	Direct on-line start	Direct on-line start	Direct on-line start
Cage internal size (L*W*H)	4500*1500*2650	4000*1500*2650	3200*1500*2650	4000*1500*2650	3500*1300*2650	2900*1270*2500
Capacity	18 m ³	16 m ³	13 m ³	16 m ³	12 m ³	7.1 m ³
Full capacity	30 person	18 person	18 person	25 person	18 person	12 person

4.1 Analysis of Type of Lift

To be able to analyze the up-down travel time of the lift, the specification of the lift was identified as described in <Table 4>. For evaluating the lifting time, rating load, operation speed and full capacity were considered by type of lift such as high speed, medium speed and low speed.

4.2 Lift Operation Hours for Manpower Transport

For analyzing the cycle time for manpower transport at Site S, the following assumptions were employed. The assumptions were developed through the consultation with the experts to enhance the reliability.

Table 5: Time per cycle for manpower transport at Site S

Category	Low speed, Small	Medium speed, Med	High speed, Large	Note
Height	105m	105m	105m	35 floors
Up	105m/40m/min =2.63min	105m/60m/min =1.75min	105m/100m/min =1.05min	35 floors
Loading	7times *0.5min=3.5min	7times *0.5min=3.5min	7times *0.5min=3.5min	at every 5th floor
Down	105m/40m/min= 2.63min	105m/60m/min= 1.75min	105m/100m/min= 1.05min	35 floors
Standby time	3min	3min	3min	
Time per cycle	11.8min	10min	8.6min	
Time per cycle for manpower transport	·200/12person =17times ·17times *11.8=200.6min (3.34hr)	·200/18person= 12times ·12times*11.8= 141.6min (2.36hr)	·200/30person =7times ·7times *11.8=82.6min (1.38hr)	Total number of person=200, based on full capacity of lift (low speed: 12, medium speed: 18, high speed: 30)
Time for manpower transport per day	3.34h*5times=16.7hr	2.36*5times=11.8hr	1.38h*5times=6.9hr	transport 5 times a day (breakfast, 2 coffee breaks, lunch, supper)

Table 6: Time per cycle for material lifting at Site S

Category	L-speed, Small type	M-speed, Medium type	H-speed, Large type	Note
Lifting height	105m	105m	105m	35-story
Loading	5 min	5 min	5 min	
Up time	105m/40m/min=2.62min	105m/60m/min=1.75min	105m/100m/min=1.05min	
Unloading	5 min	5 min	5 min	
Down	105m/40m/min=2.62min	105m/60m/min=1.75min	105m/100m/min=1.05min	
Hours	15.24 min	13.50min	12.10 min	
Time for material lift /day	·100Ton/1.2Ton= 84times ·84times*15.24 = 280.16min	·100Ton/2.0Ton=50 time ·50times*13.50 = 675.00 min	·100 ON/3.0Ton=34times ·34times*12.10=411.40min	Daily material lift is assumed 100Ton
Lift time	21.34 hours	11.25 hours	6.86 hours	

- 1) Building height: 105m (35-story building with a 3m floor height)
 - 2) Load & unloading point: at every 5th floor
 - 3) Loading/unloading time: 0.5 minutes
 - 4) Total number of workers: 200 persons
 - 5) Daily frequency: 5 times/day (breakfast, morning coffee break, lunch, afternoon coffee break, supper)
 - 6) Standby time at the ground floor: 3 minutes
- On assumption that a single lift serves 100Ton a day, the time required for material lifting a day is , as indicated in <Table 6>, 21.34 hours (low speed, small type), 11.25 hours (medium speed, medium type) and 6.86 hours (high speed, large type).

4.3 Lift Operation Hours for Material Lift

Assumption to analyze the time per cycle for material lift at Site S was made as follows. The assumption was developed through the consultation with the experts to enhance the reliability.

- 1) Building height: 105m (35-story building with a 3m floor height).
- 2) Loading/unloading time: 0.5 minutes.
- 3) Daily material lifting: 100Ton.

On assumption that a single lift serves 100Ton a day, the time required for material lifting a day is , as indicated in <Table 6>, 21.34 hours (low speed, small type), 11.25 hours (medium speed, medium type) and 6.86 hours (high speed, large type)

5. MEASURES FOR REDUCING THE SCHEDULE BY USING LIFT IN REGULAR SEQUENCE

5.1 Proposal for Using Lift in Sequence

In this study, the assumption was made to construct a 35-story high-rise apartment building based on analysis of lift up-down time. Then as indicated in <Table 7>, required time was evaluated for transporting the manpower and lifting the material in separate. It was assumed to transport the construction workers only, excluding those needed for lifting work, for 20 minutes before the time zone of 08:00 and 13:00, and because of separating the construction workers into construction workers and lifting workers, lift operation rate was assumed to be increased by 20% in time zones of 07:00~08:00 and 12:00~13:00. Though the efficiency of the lift shall be considered to develop the practical data, the efficiency of the lift was not considered due to the constraints in the study.

As a result of analysis, when the efficiency of the lift was assumed to be 100% as indicated in <Table 7>, actual operation rate of the lift was estimated as 74.5%.

5.2 Optimal Operation of the Lift

The study was intended to compare the figurers when separating them into manpower transport and material lift and vice versa.

Table 7: Proposal to separate the operation of lift into manpower transport and material lift

Time zone	Time (minutes)	Transport	Actual working hours (assumed to be 100%)
07:00~08:00	60	Construction workers only	12 (assumed to be 20%)
08:00~09:30	90	Those needed for material lifting	90
09:30~10:00	30	Morning coffee break	0
10:00~12:00	120	Those needed for material lifting	120
12:00~13:00	60	Construction workers only	12 (assumed to be 20%)
13:00~15:00	150	Those needed for material lifting	150
15:00~16:00	30	Afternoon coffee break	0
16:00~18:00	120	Construction workers only	120
Total	660 min (11hrs)	actual operation rate : 74.5%	492 min (8.2 hrs)

Though the efficiency of the lift couldn't virtually reach 100%, it was assumed to be 100% in a bid to produce the objective data on operation rate from the usual construction sites and the study. According to the study, daily actual operation rate was increased to 74.5% from 72.7% and annual actual operation rate to 52.5% from 51.1%. Work efficiency was not considered in these figures and the actual operation rate, when incorporating the work efficiency from the reliable data, would obviously increase significantly.

As part of effort to enhance the work efficiency of the lift, lift may be operated separating the manpower transport from material lift as presented in <Table 8> And reducing the number of floors where the lift stops may be one of the measures to maximize the efficiency of the equipment

6. CONCLUSION AND FUTHER STUDY

This study was ultimately intended to quantify the time required for traveling up-down so as to analyze and combine the time per cycle for transporting the manpower and lifting the material, thereby proposing the optimal operation mode of the lift. To that end, the type of lift was examined to quantify the time per cycle for manpower transport and material lift. Based on estimated time for lifting, actual operating rate of the lift was estimated for two different cases, that is, when separating the manpower transport from material lift and vice versa.

As a result, operating rate of the lift when separating them into manpower transport and material lift was found to be higher. However, the difference in data value was only 1.8% which didn't appear to be significant since the work efficiency of the lift was not considered. Should the work efficiency be considered, data value would obviously have been significant.

This study didn't focus on a way of enhancing the work efficiency in depth because of the constraints of time and environment, but it successfully quantified the lifting time through the analysis of manpower transporting and material lifting, and proposed the two alternatives aimed at improving the work efficiency. That is, operating the lift by separating the manpower transport and material lift, and minimizing the stop floors to enhance the work efficiency.

Among the constrains in this study are as follows. The time required per cycle of lift operation for transporting the manpower and lifting the material shall be applied to construction site for verification, but due to such constraints, the efficiency of the lift was not incorporated to ensure the objectivity will be secured. Making use of the preconditions for optimal operation of the lift, the efforts to enhance the work efficiency shall be further made.

The optimal operation measures developed in this study shall be applied to the high-rise building construction sites to come up with the solution for schedule reduction in the coming days.

Table 8: Comparison of annual/daily actual operation rate

Category	Time (minutes)	Actual operating rate		Actual working (assumed to be 100%)
		Annual (%)	Daily (%)	
when not separating manpower transport and material lift	660min (11hrs)	$0.71 \times 0.72 \times 100 = 51.1$ (refer to Table 2 average operating rate)	72.7 (refer to Table 3)	480min (8hrs)
when separating manpower transport and material lift	660min (11hrs)	$0.71 \times 0.74 \times 100 = 52.5$ (refer to Table 2 average operating rate)	74.5 (refer to Table 7)	492min (8.2hrs)

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