Advancement in Elevator Technology for Construction in Densely Populated Cities

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ABSTRACT

High-rise is the fundamental design criterion for construction in densely populated cities like Hong Kong. It dictates construction method, resources allocation and tender price. While conventional passenger hoist is unable to provide an effective and efficient vertical transportation in high-rise construction, JumpLift™[a] is developed to serve this purpose with due consideration on safety, productivity and quality, as well as its convertibility to a permanent lift. There are theoretical justifications for the benefits and recognition of JumpLift™. It is the attempt of this research to quantify the same in the Hong Kong construction industry from the perspective of users, developers and industry.

1. INTRODUCTION

Safety in vertical transportation for construction workers has always been a main concern of the industry. While passenger hoists are still adopting the conventional technology, JumpLift™, incorporating recent innovative developments in the concept and elevator technology, has significantly enhanced passenger safety.

With the successful application of this new vertical transportation means for construction workers, JumpLift™ has set a new standard for the industry and contributed towards a safer and healthier construction environment.

2. BASIC PRINCIPLE OF JUMPLIFT™

JumpLift™ may be defined as combining a *"builder's lift"* for construction use with a *"permanent lift"* for end users. It is designed to replace the conventional passenger hoist used on construction sites. As its name implies, JumpLift™ "jumps" as the building "grows up" and is finally converted into a permanent lift.

Contrary to a builder's lift – which is driven by rack and pinion system on an outer wall of a building – JumpLift™ is driven by traction motor using suspension steel wire ropes inside a permanently enclosed lift shaft. While providing vertical transportation for the lower floors, lift installation works are continued to extend the service floors upwards in stages in pace with the construction programme. When the lift machine room is completed, the JumpLift™ will then be converted to a permanent lift. During the conversion process, major components such as traction motor, control panel, car and counterweight slings, buffers as well as the lift shaft equipment can be retained.

3. THE JUMPLIFT™ CONFIGURATION

Figure 1 below shows the general arrangement of a JumpLift™. For illustrative purpose, this JumpLift™ is installed inside a building site at the early construction stage, providing an initial lift service from G/F to 6/F.

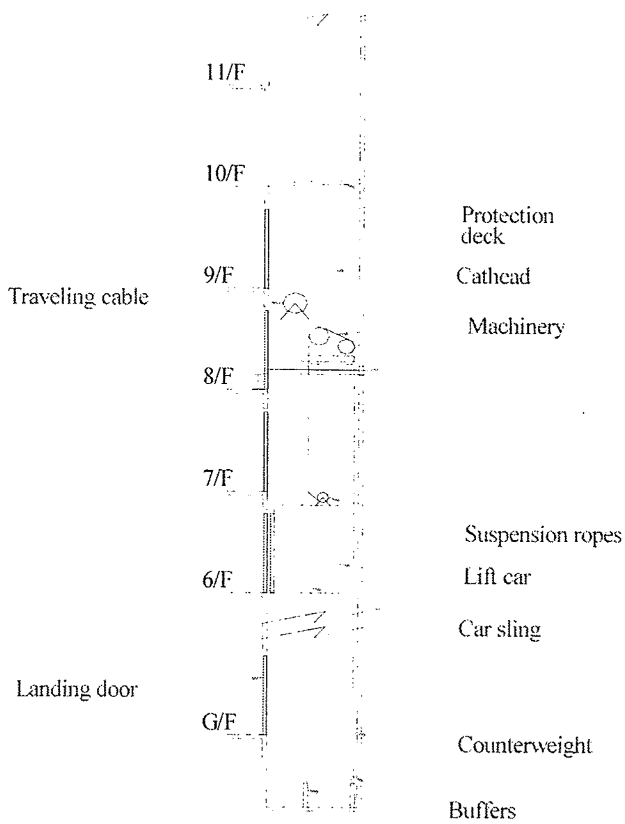

Figure 1: Configuration of JumpLift™

The JumpLift™ is installed inside a permanent lift shaft with landing doors provided on each floor according to the building design. The top of the shaft is sealed off with a protection deck at 10/F to prevent the ingress of foreign materials and water into the shaft.

The hoisting machinery and control panel are located inside the temporary machine room (called cathead) at 8/F to allow the lift car to travel from G/F to 6/F, thereby providing lift service for construction workers.

Service floors are extended upwards in accordance with the progress of the building by "jumping" the cathead to higher finished levels until the lift machine room is completed.

4. INNOVATIVE CONCEPT AND ADVANCED TECHNOLOGY

JumpLift™ is the combination of an innovative concept and advanced technology.

In the past, space utilization of a constructing lift shaft did not receive much attention. The JumpLift™ concept makes use of this space for the provision of vertical transport for the construction workers while the building is still under construction.

JumpLift™ is powered by a highly innovative permanent magnet synchronous motor named EcoDisc®[b]. The invention of this remarkable hoisting machine brings a major technical revolution in elevator engineering. This machine is a low friction gearless traction drive used in conjunction with advanced V^3F control for speed variation. With the elimination of conventional rotor winding, the permanent magnet disc rotor makes the motor more compact in size and lighter in weight without sacrificing power output. With this design, it becomes possible for a complete hoisting machine assembly to be installed inside a standard lift shaft.

5. THE JUMPLIFT™ COST MODEL

This part tries to quantify some outcomes of applying the JumpLift™ technology to high-rise buildings in the Hong Kong construction industry. In fact, most of the data comes from the research of previous studies and some of them are extracts of professional journal[1].

Due to the fact that few quantitative studies of this nature are available, it is an attempt to establish a relatively simple cost model to demonstrate the cost-effectiveness of the JumpLift™ technique. Literature reviews and surveys are carried out mainly in the construction industries of Hong Kong and the U.K. to gather some norms and means for these studies.

To summarize the findings, it is notable that one of the most outstanding quantitative achievements of the JumpLift™ application in a speculative property market situation is time saving. This in turn lowers the cost to most developers. However, there are a number of limitations on these studies because it is difficult to quantify the most frequent intangible advantages and disadvantages in this new technique in a special market environment. As this is a new attempt in the Hong Kong construction industry, further studies must be carried out to quantify other aspects of this new technology in the construction industry.

5.1 Cost Saving for Financing Land Cost

In the following, a cost model is presented to calculate the cost saving for financing land cost for a project using JumpLift™.

First, the monthly loan payment can be derived as below:

$$z = c(1+r)^{-1} + c(1+r)^{-2} + \ldots\ldots + c(1+r)^{-n}$$

$$= c\{\frac{1}{1+r}[\frac{1-(1+r)^{-n}}{1-\frac{1}{1+r}}]\}$$

$$= c\{\frac{1}{1+r}[\frac{1-(1+r)^{-n}}{1-\frac{1}{1+r}}]\}$$

$$= c[\frac{1-(1+r)^{-n}}{r}]$$

$$c = \frac{z}{[\frac{1-(1+r)^{-n}}{r}]}$$

Cost saving for financing land cost using JumpLift™ at today's price

= Net present value of total loan payment for project using passenger hoist
- Net present value of total loan payment for project using JumpLift™

$$= \sum_{t=1}^{n} \frac{c}{(1+k)^{n}} - \sum_{t=1}^{n'} \frac{c'}{(1+k)^{n'}}$$

$$= \sum_{t=1}^{n} \frac{\frac{z}{[\frac{1-(1+r)^{-n}}{r}]}}{(1+k)^{n}} - \sum_{t=1}^{n'} \frac{\frac{z}{[\frac{1-(1+r)^{-n'}}{r}]}}{(1+k)^{n'}}$$

where

z	=	loan amount (land cost + stamp duty + solicitor's fee)
c	=	monthly loan payment for project using passenger hoist
c'	=	monthly loan payment for project using JumpLift™
r	=	monthly interest rate (r = i/12, whereas i is the annual interest rate)
n	=	number of terms for project using passenger hoist
n'	=	number of terms for project using JumpLift™
k	=	monthly required rate of return (k = g/12, whereas g is annual required rate of return)

Work Example:

Take a construction site as an example and the loan amount z to be $312,000,000.00. Assume the annual interest rate i is 13% and the annual required rate of return g is 7%. Thus the monthly interest rate r is 1.0833% and the monthly required rate of return k is 0.5833%. When using a conventional passenger hoist, take the number of terms n to be 36 months. This can be shortened to 34 months (n' = 34) if JumpLift™ is applied.

Cost saving for financing land cost using JumpLift™ at today's price

= Net present value of total loan payment for project using passenger hoist
- Net present value of total loan payment for project using JumpLift™

$$= \sum_{t=1}^{n} \frac{c}{(1+k)^{n}} - \sum_{t=1}^{n'} \frac{c'}{(1+k)^{n'}}$$

$$= \sum_{t=1}^{n} \frac{\frac{z}{[\frac{1-(1+r)^{-n}}{r}]}}{(1+k)^{n}} - \sum_{t=1}^{n'} \frac{\frac{z}{[\frac{1-(1+r)^{-n'}}{r}]}}{(1+k)^{n'}}$$

$$= \sum_{t=1}^{n} \frac{\frac{312{,}000{,}000}{[\frac{1-(1+1.083x10^{-2})^{-36}}{1.083x10^{-2}}]}}{(1+5.833x10^{-3})^{36}} - \sum_{t=1}^{n'} \frac{\frac{312{,}000{,}000}{[\frac{1-(1+1.083x10^{-2})^{-34}}{1.083x10^{-2}}]}}{(1+5.833x10^{-3})^{34}}$$

= \$340,463,129.38 - \$338,941,186.89

= **\$1,521,942.49**

The result shows a cost saving of around \$1.5M for financing land cost using the JumpLift™ technology.

5.2 Total Cost Comparison between JumpLift™ and Passenger Hoist[2]

Taking the running cost into consideration, the total cost in relation to the duration for a conventional passenger hoist and JumpLift™ are shown in Figure 2 on the next page.

For JumpLift™, the cost calculation is based on the following assumptions:

- Material cost for convertible components is not included but the cost to make good convertible components is included.
- Re-usable components are subject to a linear depreciation of 20% per use.
- JumpLift™ is rated at 900 kg and is running at 1.6 m/s.
- For comparison purpose, JumpLift™ jumps every 6 floors. In reality the number of jumps may be more subject to actual construction planning. Hence the cost may increase.

For passenger hoist, the cost calculation is based on the following assumption:

- The passenger hoist is rated at 1,300 kg and is running at 0.65 m/s.

The costs of JumpLift™ are shown separately for private sector housing and public sector housing subject to a different split of convertible / re-usable components.

It should be noted that the comparison between JumpLift™ and conventional passenger hoist is not exactly on identical terms. The passenger hoist is on a rental basis. Nevertheless, the total costs for JumpLift™ (private sector housing) and passenger hoist are more or less the same after 18 months of operation. JumpLift™ (public sector housing) remains the most expensive as only nominal components are retained when converted to a permanent lift.

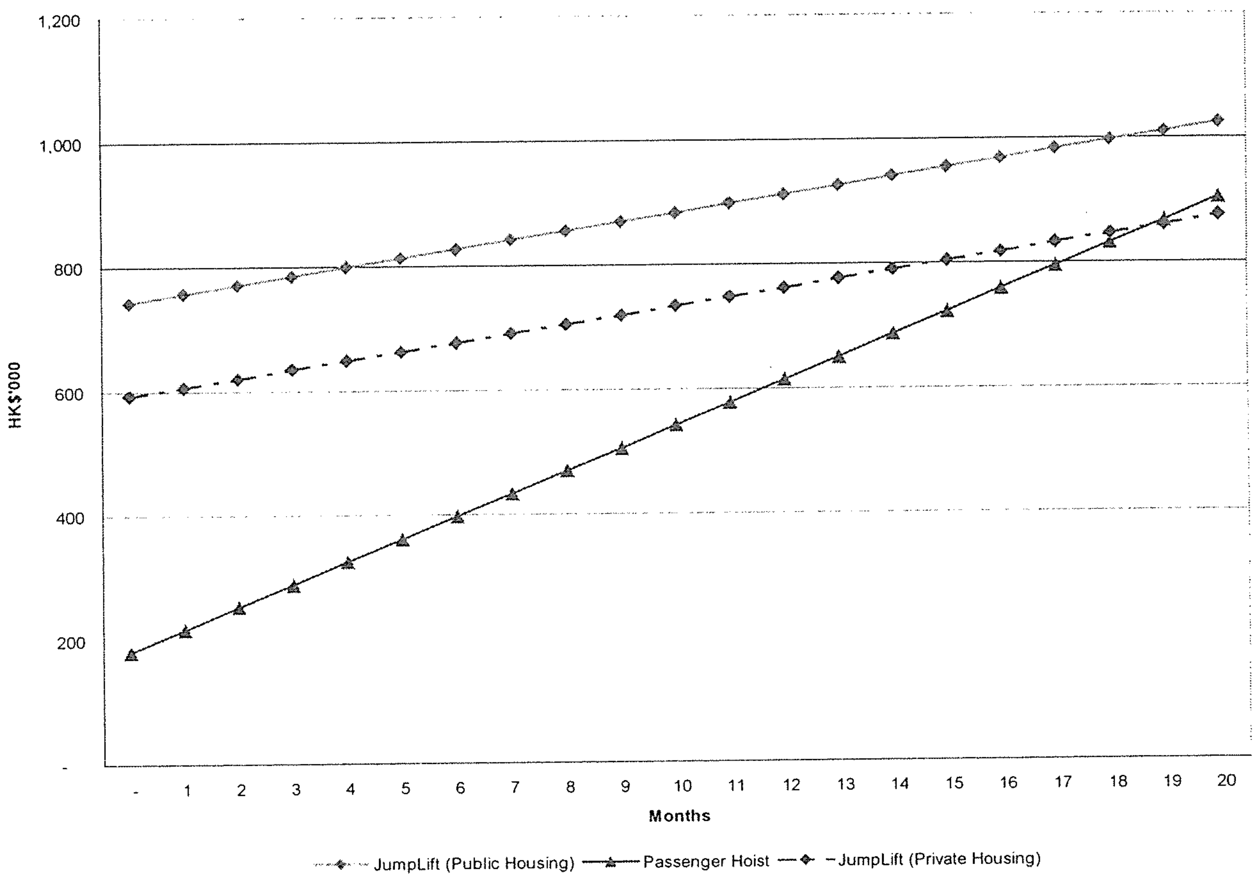

Figure 2: Cost Comparison

5.3 Further Studies

The above cost model quantifies the cost saving when using JumpLift™ technology by considering possible time saving in the overall development process. The model is independent of other data that are not significantly affected by the time saving concerned (i.e. professional fees, advertising, marketing, etc.). Again, the model is derived from previous research data where the prevailing standard land lease, stamp duty, development criteria, procedures and the like are considered.

This study cannot and is not intended to quantify the intangible benefits and limitations of the application of JumpLift™ in the Hong Kong construction industry. Further in-depth studies are to be made to cover a wider spectrum including safety, quality, environmental issues, site culture, mentality of workers, synergy effect between builders and sub-contractors on the one side and all other possible limitations on the other.

6. A CASE REPORT

The JumpLift™ technology was first applied in Hong Kong at the construction project *"Private Sector Participation Scheme Development, Tseung Kwan O Town Lot No. 62, Tseung Kwan O Area 65A, Tseung Kwan O" (Project TKO62 PSPS)*. The project comprises eight residential tower blocks, plus a car park and shopping centre. Each residential tower block is 40 storeys high, and is serviced by two low zone lifts (serving G/F to 20/F) and two high zone lifts (serving G/F, 21/F to 40/F). The final configuration of the permanent lifts being:

- Low zone (Lifts No. 1 & 2) – 900 kg / 12 persons / 1.75 m/s
- High zone (Lifts No. 3 & 4) – 900 kg / 12 persons / 3.5 m/s

The scheme adopted the use of one unit of JumpLift™ per block for two of the residential tower blocks. The project team's decision was to apply the JumpLift™ system in Blocks 1 and 2, using the high zone lift shaft no. 4 in both residential tower blocks.

6.1 Design Features Adopted for JumpLift™ System

Rated load – The rated load of the JumpLift™ is dictated by the size of the lift shaft. Therefore its maximum rated load cannot exceed that of the permanent lift, i.e. 900 kg for Project TKO62 PSPS.

Rated speed – The maximum rated speed of the JumpLift™ is limited to not exceeding 2.0 m/s by local code[3]. The rated speed of the JumpLift™ is designed to be 1.6 m/s.

Drive arrangement – The choice of drive arrangement is made to provide the most convenient solution. A "bottom-mounted" arrangement will take up the lowest floor as the temporary lift machine room. Since there is neither basement nor podium floors, the top-driven arrangement is chosen to maintain a free access from the G/F level.

Floors served – The JumpLift™ stops at every floor covered by the lift travel. Additional temporary openings have to be reserved at low zone floors for this purpose and later made good upon final conversion to the permanent lift.

Jump interval – A 3-floor jump is considered appropriate for Project TKO62 PSPS.

Mechanism of jump – Steel core-forms are used for construction of the lift cores in Project TKO62 PSPS. This construction method causes difficulties in using the tower crane for lifting the JumpLift™ equipment in the jump process. A "self-jump" mechanism using an electric chain hoist is used which saves the trouble of arranging special craneage time of the tower crane.

Conversion to permanent lift – To ease the client's serious concern regarding the perception of lift equipment as "second-hand", all JumpLift™ equipment will be replaced except the guide rails and their mounting brackets when converting to a permanent passenger lift.

6.2 Review of Actual Results Achieved

The JumpLift™ system was first put into service on 22 September 1999 in Block 1, and 5 October 1999 in Block 2 of Project TKO62 PSPS. Both of them were decommissioned on 15 August 2000. The following are a list of benefits made from the viewpoint of the builder:

Not affecting façade finish – The JumpLift™ system adopted for use in Project TKO62 PSPS was installed inside the lift shafts. There was absolutely no effect on the external façade works. This benefit is considered fully achieved by the builder.

Continuous monitoring of lift shaft dimensions – As guide rails are installed in pace with the progress of structural construction work, checking of the dimensions and verticality of the lift shaft are done promptly and continuously.

Lifting capacity – The rated load of the JumpLift™ was dictated by that of the permanent lift, i.e. 900 kg in the case of Project TKO62 PSPS. Although the lifting capacity of the JumpLift™ was lower than that of the passenger hoist (1,300 kg), the convenience, efficiency and speed of operation of the JumpLift™ had more than made up the difference.

Speed of travel – The rated speed of the JumpLift™ was 1.6 m/s. Comparing with the speed of the passenger hoist (i.e. 0.5–0.7 m/s), the efficiency of operation was much better as demonstrated by the frequency of usage of the JumpLift™.

Operation not hindered by adverse weather – Throughout the usage period of the JumpLift™, the equipment had been well shielded from the weather by the protection devices designed and installed for the application. A set of purpose-built weatherproof decks was provided above the cathead and had been performing very well in keeping rainwater away from the lift shaft and equipment underneath. The installation worked extremely well and enabled continuous lift service even in very adverse weather conditions.

Operational safety – The JumpLift™ installation adopted for use in Project TKO62 PSPS incorporated the following safety features, which well surpassed the conventional passenger hoist:

- Totally enclosed car cage similar to permanent passenger lift design
- Solid lift doors similar to permanent passenger lift design
- Lift car sufficiently lit up with fluorescent light
- Automatic leveling of lift car
- Overload protection with alarm

The constant presence of the lift installation team on site provided instant and prompt maintenance services that further assured operational safety and reliability of the JumpLift™.

Environmentally friendly – As JumpLift™ was installed inside the enclosed lift shaft, noise and dust emission to the surroundings was kept to a minimum. The "jump" operations were performed at night but due to the silence of operation and the acoustic insulating effect of the centrally located lift shaft, there was no problem in the application for the construction noise permit for the work.

Scaffold-free lift installation method – The JumpLift™ installation employed the "scaffold-free" installation method. The conventional bamboo scaffold was not required. Instead a set of aluminium scaffolding spanning only three floors fixed on top of the cathead was used for the installation of the lift shaft equipment. This improved safety during the erection process reduced the need for making good work that would have been caused by the erection of the bamboo scaffold.

Service available for all floors – The JumpLift™ system adopted at Project TKO62 PSPS made a 3-floor jump according to Table 1 below:

Table 1

Topmost Floor Served	Block 1	Block 2
6/F	22/09/1999	-
9/F	29/09/1999	05/10/1999
12/F	05/10/1999	11/10/1999
15/F	21/10/1999	01/11/1999
18/F	15/11/1999	22/11/1999
21/F	30/11/1999	06/12/1999
24/F	17/12/1999	28/12/1999
27/F	08/01/2000	17/01/2000
30/F	26/01/2000	02/02/2000
33/F	21/02/2000	28/02/2000
37/F	01/04/2000	06/04/2000

After each jump, lift service was available for all floors from G/F up to the topmost floor, giving the best transportation efficiency.

Improved productivity – Work progress for the following trades involving bulky material indicated a general picture of the difference in residential tower blocks using the JumpLift™ system versus that using the conventional passenger and material hoists (Table 2).

Table 2

Work Item	Progresss to Date	Progress up to (Floor No.)			
		JumpLift™		Passenger & Material Hoists	
		Block 1	Block 2	Block 4	Block 7
Timber door frame	02/01/2000	26/F	24/F	21/F	20/F
	06/03/2000	35/F	33/F	30/F	29/F
	30/03/2000	38/F	35/F	33/F	31/F
	29/04/2000	40/F	40/F	38/F	38/F
Window frame	02/01/2000	19/F	20/F	15/F	16/F
	06/03/2000	33/F	33/F	30/F	31/F
	30/03/2000	34/F	34/F	31/F	32/F
	29/04/2000	40/F	40/F	38/F	37/F
Bath tub	02/01/2000	4/F	5/F	4/F	3/F
	06/03/2000	14/F	15/F	13/F	11/F
	30/03/2000	20/F	20/F	16/F	13/F
	20/04/2000	29/F	29/F	23/F	20/F

Progress of works for these trades in Blocks 1 and 2 using the JumpLift™ system was generally ahead of that for Blocks 4 and 7 using the conventional passenger and material hoists. The productivity of overall building activities had improved by 19% by using the JumpLift™ technology.

Availability of permanent lift service – To cater for the extensive works needed to convert to the permanent lift installation, JumpLift™ system for Blocks 1 and 2 was taken out of service for decommissioning on 15 August 2000. Conversion works were completed within 45 days, and a permanent lift service was made available well before the project completion date.

Maintaining lift service – Continuous service of vertical transportation was maintained throughout the construction period. While the JumpLift™ service was suspended for 45 days at the conversion phase, other lifts in Blocks 1 and 2 were already available to provide uninterrupted lift services.

7. CONCLUSION

JumpLift™, with its innovative concept and advanced technology, has set a new standard of vertical transportation for the construction industry. Its advantages of more stringent safety provisions, fast speed, high traffic handling capability, accessibility to every floor, as well as all-weather operation provide construction workers with an efficient and effective means of lift service. This improved service better facilitates site installation, supervision, inspection, as well as quality control, which in turn lead to a shortened construction cycle.

From the case report, observations showed that the productivity of overall building activities improved by 19% by using JumpLift™ technology. There is, however, still room for enhancement. In the case report, the JumpLift™ and conventional passenger hoist were applied with identical project planning. If project planning were specially programmed for the JumpLift™, the productivity of overall building activities would definitely be further improved.

In densely populated cities like Hong Kong, the building construction industry is usually planned in fast track operation. However, project planning is usually constrained by inefficient and ineffective vertical transportation. JumpLift™ will therefore be the solution. For the sake of further developing our construction industry, it is absolutely worthwhile to explore more from the JumpLift™ technology, especially in regard to legislation, monitoring and promotion.

8. REMARKS

[a] JumpLift™ is a trademark of KONE Corporation.

[b] EcoDisc® is a registered trademark of KONE Corporation.

9. REFERENCES

[1] The Hong Kong Institute of Surveyors Journal, Vol. 11, Issue 1, March 2000.

[2] Extracted from "Innovative Concept = JumpLift Application in Building Construction". Lee, Rowson K. H., Lam, Dante C. M., and Yung, C. M. (March 2000). *The Hong Kong Institute of Surveyors Journal*, Vol. 11, Issue 1, pp.14-21.

[3] Hong Kong Code of Practice on the Design and Construction of Builders' Lifts (1996)