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Exploration on selection and optimization of vertical transportation system (Elevator) for commercial buildings

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ABSTRACT

This paper presents a study on the selection and optimization of the elevator system for commercial buildings. Since the elevator industry began in 1853, elevators become more and more common in people's daily life. Now, elevator system design is an important part of commercial building service design. A good elevator system can contribute marks for the performance of commercial building. This study includes an assessment of the utilization of this vertical transportation to run the daily matters of the building productively and safely according to the regulations and standards. In addition, it will also look into the method to arrange the transportation in a building which has high-flow of people. 1st Avenue Penang, Malaysia is chosen as the observation site in this study. It is hoped that this study will provide some useful insight on the transportation system (elevators) in the commercial building.

Introduction

The mechanical transportation could be found within, around and in general association with modern buildings and developments include: elevators, escalators, paternosters and travelators. An elevator is vertical transport equipment and used to transfer people or freights between floors inside structures (Figure 1a). An escalator is a moving staircase. It provides a transport service for carrying people between floors of a building (Figure 1b). A paternoster is a passenger elevators which comprises of a chain of open compartments. It moves slowly without stopping in a circuit up and down inside a building (Figure 1c). A travelator is a slow moving conveyor mechanism. It can transfer people over a short to medium distance across a horizontal plane (Figure 1d).

(a): Elevator in office building

(b): Escalator in a shopping complex

(c) Paternoster located in a office building

(d) Travelator in an airport

Figure 1: Different types of vertical transportation system

Inside general commercial buildings, there are usually two types of vertical transportation that can be found: elevators and escalators. This research will focus on the elevators. In commercial buildings, the transportation system must be able to face the high population flow. A good transportation system can be a tool to maintain the convenient and comfortable environment of the commercial buildings. It should be strong enough to support the normal works in and around the commercial buildings.

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This paper focuses on investigating in detail the transportation system (elevator) in commercial buildings as well as to determine how to arrange transportation bodies in a building that has high-flow of people. It will also find out how to utilize the vertical transportation (elevator) to run the daily matters of the building productively and safely according to the regulations and standards.

1st Avenue Mall Penang has been chosen to be the observation site for this research. It is located at Carnarvon Street. The building was officially opened for business on 25 November of 2010. This complex has a complete transportation system to carry the high population flow. 1st Avenue Complex occupies a 10,126 square meter plot. The capacity of the elevator is 1670 kg for 24 people. The outside view of 1st Avenue Penang is shown as Figure 2.

Figure 2: The outside view of 1st Avenue Penang

Methodology

In order to conduct on-site observation at the 1st Avenue Penang, there is a set of procedure that must be followed:

Firstly, the approval should be obtained from the maintenance office of the 1st Avenue Penang. After obtaining the approval, the interview would be conducted after making an appointment with the operation manager. More information about the elevators is available from the interview. After the questionnaire is designed, the survey will be conducted. The questionnaire survey among the customers and salesmen is useful in proving an insight on their views, attitudes, and thoughts on the transportation system (elevators) inside the mall. The proper time and locations for the on-site observation could be settled after the interview and questionnaire survey. A lobby count of traffic on and off the elevators is the simplest method to get useful information. Considerable information is obtained through good observations in the lobby during the morning, noon, and evening peak period. This information includes the way the elevators operate, people's feelings, interval, bunching, the car loading, and the door operation, also elevator-handling capacity. On-car traffic counts require the observer to stand inside the car and record the traffic in each direction and time when the elevator leaves, reverses or waits. Performance evaluation is conducted at any time to record the time when the door starts closing or opening, when the car starts or stops.

Observation, Results and Data Analysis

Interview

An interview was conducted at the maintenance office of 1st Avenue Penang. The peak traffic period is from 12:00pm to 8 pm. The height of one floor is 15ft. Floor plans and some maintenance reports of the elevators were collected from this interview.

There are six passenger elevators provided in the shopping mall. Two elevators are in a group. One group is located beside the East Gate. The second group is located beside the South Gate. The third group is located beside the West Gate. The locations of the elevators follow the locations of the mall's gates. This arrangement would make it much easier for people to find the elevator even they just enter the shopping mall. Figure 3 shows the ground floor plan.

Figure 3: Ground Floor Plan

Questionnaire survey

The questionnaire consists of 18 questions. 100 respondents answered the questions and returned the survey questions to the researcher. Statistical Package for the Social Sciences was used to analyze the answers.

Most respondents wish to use the group which is near the restrooms. Then on-site observation can be conducted with this group. However, some respondents think that it is difficult to find the elevators. Most respondents are satisfied with the ventilation system in the elevators. A few respondents are unsatisfied with the waiting time; they think, the speed of elevators should be increased. A number of the respondents think that the elevator is narrow when they are inside the elevator. All respondents have not experienced any incidents inside of the elevators. The elevators work well. Most of the respondents agree that the elevators' system adds marks for the performance of the shopping mall.

Lobby count

The procedure of a lobby traffic count is conducted in this manner: one observer stands towards the elevators and records the number of people who enters and leaves each elevator when it arrives. This is done for 5-min periods with other events observed. These events are people backing up in the lobby, interferences with the operation, the bunching of elevators, a number of cars arriving or leaving together within a short time, and the carrying of packages, freight, or carts on elevators, as well as other unusual occurrences.

In this study, the observation and recording are conducted during the morning peak from 12:00pm to 1:00 pm, and the night peaking from 4:00 pm to 5:00pm and 6:00pm to 7:00pm.From Table 1,on Sunday, the period from 12: 00 pm to 12:05 pm carries the heaviest traffic from observation. The peak traffic is around 17 in 5-minute periods.

Dividing the total number of trips into the whole periods in seconds, then the average interval is obtained. A sample of the result is shown in Table 1.

From the observation on Sunday, the average loading interval of the elevators is 30 sec. The process is hard for an observer to cut off counting at the exact end of five minutes to start the next period, so it is necessary to average the interval over a period.

On-car traffic count

It is necessary to ride the elevators to survey the traffic. Records of the traffic in each direction and the time the elevator leaves the landings, reverses, or waits are shown in the tables below. If no one got on or off, zero will be marked. If there is an arrow changing from an up-to-down trip, this means the elevator reverses before reaching a terminal. Each stop is recorded.

It is possible to determine the inter-floor traffic by comparing the survey taken on several elevators over 5-minute periods. Table 2 shows the result of an on-car traffic count carried out on Sunday.

Performance evaluation

Performance evaluation is a traffic test which can be performed at any time. This test simply requires a stop watch. An observer should be inside of the car to record the time when the door closes, the car starts, door–open time, floor-to-floor travel, and the amount of time spent at a floor. Figure 4 shows the form which can be used for in-car performance evaluation. The different times are developed either by direct readings or the difference between events. The data from the performance evaluation can be used to do many important calculations, such as speed of the elevators, interval and round-trip time, etc.

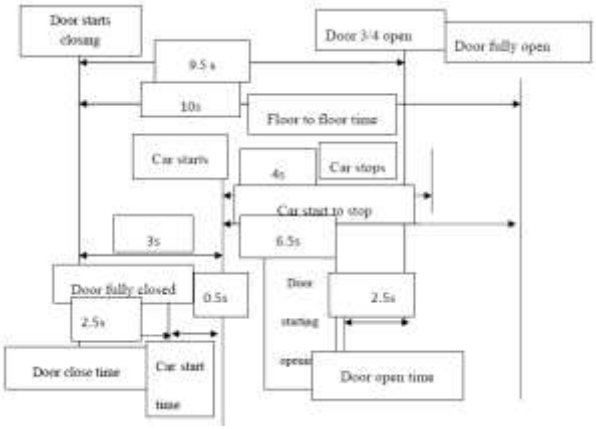

Figure 4 Performance time chart for an elevator floor-to-floor travel showing the various elements of a one-floor elevator trip

Speed

The height of one floor is 4.752m, the time of the car traveling across single floor is 4s, speed of elevator =height of one floor/ inter-floor flight time = 4.752/4=1.188m/s.

According to Roger (1997), the general rules for the passenger elevator speeds for various travel distances are shown in Table 3:

In low-rise buildings, the speed should be 0.3m/s for a passenger elevator. A higher speed limit for tall buildings is about 7m/s. There are 10 floors in the building, so the speed of the car in the general rules should vary from 2m/s to 5m/s. The speed of the elevator inside 1st Avenue Complex is lower than the minimum standard. It will cause delay of the service.

Round-trip time

A practical procedure is to break the trip down into its components to calculate the total time for a elevator trip. The following steps will illustrate the procedures of the elevator (the elevator t is assumed to stop at each floor).

When the passenger arrives and operates the call button, a car at the lowest landing, the elevator door requires (a sec) to open. Passenger must be granted with reasonable time (b sec) to enter the car and operate car buttons. Doors must be closed (about (a) sec) throughout the travelling of the car (one floor distance to the next landing).The doors will open again. It will take another (a sec) to open. After this, the elevator will allow another (b sec) for a passenger to leave, and another one enters and operates the car button. The process will continue again. It is assumed that the car will stop at each floor. When the car arrives at the top floor, the total time will be [3(a) +2(b) +(c)] ×9.

The car starts to return to the lowest floor. The process will be repeated. The door will be closed again (a sec) and return to the lowest floor(c*9 sec). The time will be a+9c.

From the observation, a=2.5 s, b=2s, c=4s, so the RTT= [3(a) +2(b) +(c)] ×9+a+9c=178s.Each of them is with a round trip time of 178sec.

Interval

There are two elevators in a group, according to Barney (1977), the interval = round-trip time of an elevator/ number of elevators in the group which is 178s/2=89s. The suitable interval for commercial buildings varies from 20-30s. The actual interval of the elevators is longer than the maximum standard. This will lead to longer waiting period for an elevator and eventually reduce the quality of the service.

Waiting time

The average waiting time is about 55 to 60% of the interval. The average waiting time is around 44.5sec. According to the standards (Barney, 1985), average waiting time should be less than 30 sec in commercial buildings. People will be unsatisfied with long waiting period.

Elevator platform shape

The capacity of the elevator is 24 persons; the total platform area is 38.75 ft². The area per person is (38.75 ft²/24=) 1.61 ft². An average area for a passenger is required about 3 ft² of floor area to make the passenger comfortable (Barney, 1985). Passengers can be crowded to a minimum of about 2 ft² for the average person. The actual area is less than the minimum requirement. People may feel uncomfortable because the elevator car is too narrow.

Conclusion

In 1st Avenue Penang, there is a complete transportation system to face the high population flow. The good elevator system can add marks for the performance of the complex. When a designer starts to design a system, he or she should be clear and make sure that the system is according to the standards. Furthermore, he or she should take the local condition and the quality of service into the consideration.

A good elevator system is not only focused on the features of the elevators because the arrangement of transportation bodies should be also designed properly. The location of the elevators in the commercial building should be easily accessible. Usually, the location of elevators would follow the location of the entrances. When people are inside the complex, the elevators should be easy to find, and should not be far away from the users. More than one elevator stand side by side will shorten the waiting time for the passengers. Passengers will not be satisfied with a long waiting time. A commercial building usually has a combined system of the elevators and escalators. When people want to travel between a long distance, they will choose to use the elevators. This composite system will help separate the pressure of the traffic.

Not only the selection of the elevator system is important, but also the maintenance of the system. The elevator's car should be cleaned every day. The people will be uncomfortable inside the car if it is dirty. And all elements inside the car should

be workable for running the daily works. Regular checking process should be carried out by the qualified person using the proper checklist provided by the elevator company or the government.

Acknowledgement

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Table 1 Tabulation of pedestrians on and off elevators at a lobby floor (Sunday)

No	Time		Up elevator traffic(Sunday)					No. Pass entering
	Hour	Minute	Number of passengers entering at 1st floor(by car load)					
2	12	00—05	10	0	2	5	0	17
		05—10	0	6	0	7	0	13
		10—15	1	0	1	1	0	3
		15—20						
2	4	20—25	0	5	1	0	7	13
		25—30	4	1	0	0	0	5
		30—35	1	0	0	3	6	10
		35—40						
2	6	40—45	1↑	4↑	1↑	7↑	4↓	13↑4↓
		45—50	9↓	0↑	4↑	2↓	3↑	7↑11↓
		50—55	0↑	5↑	1↓	8↑	3↑	16↑1↓
		55—60						
Down elevator traffic			Number of passengers leaving elevator car					No leaving
2	12	00—05	9	0	1	3	1	14
		05—10	0	0	5	0	8	13
		10—15	0	7	0	6	0	13
		15—20						
2	4	20—25	0	6	0	5	0	11
		25—30	5	0	3	2	0	10
		30—35	0	4	0	5	2	11
		35—40						
2	6	40—45	1↑	2↑	0↑	9↑	3↓	12↑3↓
		45—50	5↓	2↑	0↑	5↓	0↑	2↑10↓
		50—55	1↑	7↑	5↓	0↑	2↑	10↑5↓
		55—60						

Table 2 Tabulation of pedestrian movement on and off an elevator observed from within the elevators (Sunday)

On-car traffic test(Sunday)													
		Floor	LG	G	1	2	3	4	5	6	7	8	
Up	ON	TIME	9										
	OFF	18:01:31				2			3	1		3	
Down	ON	TIME					8					3	
	OFF	18:03:21		1	7			2		1			
UP	ON	TIME	5		1								
	OFF	18:04:01					3		3				
DOWN	ON	TIME			4		8		0				
	OFF	18:05:31	3	1		4							
UP	ON	TIME	0	3	2	9		6	1	3	1		
	OFF	18:09:30				5	5		3	7		5	
DOWN	ON	TIME			6			1		6		0	
	OFF	18:11:21	6	1			1		5				
UP	ON	TIME	0	5			2	5		1			
	OFF	18:13:42				3			4	2	3	1	
DOWN	ON	TIME						3		6		6	
	OFF	18:15:02	5		3	3			4				

Table 3: Passenger Elevator elevator speeds (Roger, 1997)

Floors	Car speed m/s
Up to 4 floors	0.3-0.8
4-9 floors	0.8-2.0
9-15 floors	2.0-5.0
Over 15 floors	5.0-7.0