SIMULATION ANALYSIS OF FREIGHT DELIVERY SYSTEM WITHIN A COMMERCIAL OFFICE BUILDING

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Abstract: This paper tries to assess the effect of cooperative delivery system to one of the buildings inside Marunouchi District in transporting goods to different floors. Several models are developed to provide alternatives to the present delivery system. The data used on the study was taken from actual experiment of TDM implementation enforced in Marunouchi in Feb 2002. The said experiment aims to improve the traffic flow and to reduce the alarming increase of harmful chemicals emitted by vehicles particularly from trucks. The paper also tries to examine the potential and accuracy of PEAMON in monitoring activities of workers employed to deliver the goods. Results tend to suggest that the two workers employed in the building are under utilized while PEAMON shows promising results in monitoring workers activities that leads to the identification of the location of goods.

Key Words: ProModel, PEAMON, Marunouchi, simulation, cooperative delivery

1. INTRODUCTION

Marunouchi District, located beside Tokyo Station and one of the biggest business districts in Tokyo, is undergoing a major renovation. Its old commercial office buildings are remodeled and converted into high-rise to accommodate economic and technological demands. Also included in this infrastructure renewal is the improvement of its avenues. The redevelopment project is designed to cater different types of businesses such as media companies, financial institutions, foreign firms, and shopping district.

An actual experiment of TDM implementation was enforced for about a month in early 2002. One component of the experiment is a 30-minute free parking charge located at the underground floors of most of the buildings. This strategy is designed to reduce the number of vehicles usually parked illegally on the already congested streets. Another component of the experiment was the enforcement of cooperative delivery of goods coming into the area. A stock-point station was set up around 500-meters away. Aside from decreasing the number of illegally parked vehicles, another concern of the experiment is to reduce the continued rising of nitrogen oxide (NOx), suspended particulate matter (SPM) and other harmful chemicals emitted from motor vehicles, particularly from trucks.

While the experiment was in place, coordinated surveys were conducted. These surveys were meant to document the effect of the experiment to the behaviors of vehicles and to the method of the delivery of goods. Data obtained from the surveys will then be use to assess the overall impact of the experiment. If the experiment found to be effective, it will be enforced or otherwise revised. The data used on this study was taken from these surveys particularly from the survey of cooperative delivery system. Although complete set of data is available, this study will only focus on the effect of cooperative delivery practice on vertical movement of goods inside the building. In particular, this study will assess the performance rate of the workers assigned to facilitate the movement of goods inside the building and evaluate the potential of the surveillance device used in gathering the data.

Urban freight transport and logistics studies recently gained wide recognition mainly due to their economic role and concern to their impact to the environment. However, still, it is not that usual to locate a study wherein the relationship of road traffic (delivery truck) and the offloading chain inside the building is clarified. This study, aside from widening our understanding to goods movement as general, hopes to contribute in the effort to come up a method that could accurately document the activities involve in transporting the goods. This newly introduced method of documentation is significant to clarify the functions of logistics elements – workers, elevator, docking area- that could determine the efficiency of the system.

2. LITERATURE

The significance of understanding the whole process of delivery of goods inside CBD has become more important since many studies point out that delivery trucks have a high share of participation for the traffic problems. Incidents such as concern for safety, sharp rising of NO_x, CO_2 and other negative effect to the environment, noisy and producing strong vibration are all familiar attributes to goods vehicle. In trying to address these problems, several study approaches has been made accounting series of actions required to transport goods.

Simulation analysis approach is one familiar strategy and perhaps the most effective tool in explaining the material flow. Park et al (1998) simulated the three types of loading/unloading station, i.e. street parking, off street parking, and docking area inside the building, and compare the time spent by each vehicle before leaving out. The offloading chain was also simulated using WITNESS simulation package. The research concluded that there were only very slight difference between the results of simulation and done manually thus the authors affirmed that simulation approach could explain the whole supply chain.

In New York, Morris et al (2001) found out that a freight vehicle in the central business districts averaged 33 minutes to unload goods both at the side of street and at the dock located at the underground floor of the building. This study concluded that often time, the limited capacity of freight elevator causes the longer time delivery or in worst case, the building lacks this freight facility. Situations like these force the goods carriers to utilize the stair or mix up with the passengers in the passenger elevator further prolonging the delivery time.

Ma, Liying (2001) organized the variables necessary for simulation model of loading and unloading of goods in her studies entitled “Urban Goods (Off) loading Chain”. The paper is rather a conceptual, identifying the activities and formulates the structure of the simulation model. The study appears to be complementary to the study done by Park et al noting that most of the variables except “hindrance”, “total emission”, “noise level” were already included to the simulation study of Park. Nonetheless, this study presented a good conceptual analysis on how to tackle the goods processes for simulation inside a commercial building. Recent years paved way to the evolution of several activity monitoring devices. One of these is the PEAMON (Personal Activity Monitor) which although newly developed surveillance device but already gained wide recognition. Asakusa et al produces several papers exploring the potential and accuracy of this device in monitoring the activity of individual holders. For instance, "Monitoring Personal Travel Behavior using a Cellular Phone System with Power Antennas and CSID Analysis" traces the routes of PEAMON holders and explain each mode involve in his route. Tanaka et al (2001) also used PEAMON in his study entitled "Reconstruction of Spatio-temporal Distribution of Event Visitors by Fusing Multi-source Data".

3. SURVEY IN DETAIL

3.1 Surveyed data

The data obtained from trucks delivering goods during the three (3) day experiment are shown in Table 1, 2 and 3. Observations suggest that time interval from each trip in the early morning delivery is very short - for instance is the time interval between the first trip and second trip on Table 1. The first delivery truck arrived at 8:48 carrying 14 goods and followed shortly by another vehicle transporting 16 goods at 8:52 resulting to 4 minutes time interval between the trips. It is believed that in this part of the day, most business establishments and offices are storing goods supplies that could at least serve the whole day. This might be the primary reason that could explain on why there is a big amount of goods to each trip having very short time interval.

Table 1. No. of truck trips and goods delivered (2/19/2002)

Date	Arrival time	No of goods
2/19	8:48	14
2/19	8:52	16
2/19	8:53	32
2/19	9:04	39
2/19	9:22	4
2/19	9:39	1
2/19	14:56	2

Table 2. No. of truck trips and goods delivered (2/20/2002)

Date	Arrival time	No of goods
2/20	8:37	13
2/20	8:46	30
2/20	8:47	2
2/20	9:07	6
2/20	9:10	36
2/20	9:24	12
2/20	10:08	1
2/20	10:48	2
2/20	11:11	2
2/20	13:09	1
2/20	14:04	1

Table 3. No. of truck trips and goods delivered (2/21/2002)

Date	Arrival time	No of goods
2/21	8:36	11
2/21	8:46	31
2/21	8:46	2
2/21	9:09	9
2/21	9:17	35
2/21	9:47	8
2/21	13:09	12

As far as vehicle trip is concern, there are seven (7) trips on Feb 19, eleven (11) trips on Feb 21 and seven (7) trips on

Feb 21. With regard to the number of goods delivered, total number of goods reached the building on Feb 21 is 108, 106 on Feb 20 and108 on Feb 21. The number of goods arrived the building on Feb 19 and 21 have the same amount, which interestingly produced the same number of truck trips.

3.2 PEAMON as a tool in tracing the delivery floor of goods

3.2.1 Description of PEAMON

Asakura et al (2001) describe it as a pocket-size travel data collection equipped with PHS (Personal Handy phone System) receiver, three-dimensional acceleration sensor, CPU, compact flash memory card and powered by lithium ion battery (Figure 1). The unit's size is 120 mm in height, 12 mm in thickness, and has a weight of 125 gram. The location positioning data (longitude, latitude, and time) is generated every 15 seconds via its built-in PHS function. This travel-monitoring unit uses the signal strength and the ID number of 3 to 7 base stations of PHS communication system capable of monitoring activities for 48. Its durability is further enhanced by a special function called "turns to sleep mode" when the acceleration signal is weak.

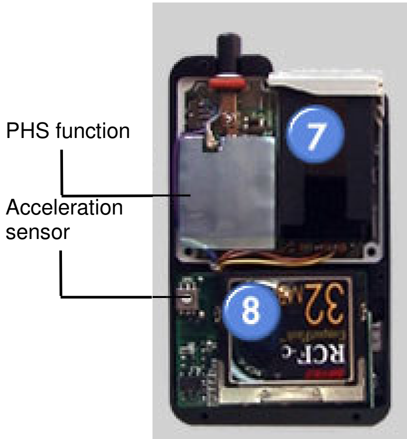

Figure 1. PEAMON model showing its built-in equipments

3.2.2 Monitoring the Goods Offloading Chain

PEAMON's signal is relying to the power of base station and therefore cannot record with the absent of signal. In order to mitigate this difficulty, a Power Antenna (PA) with range of 300 meters was installed to each floor of the building totaling to 19. These PAs, which solely developed to support PEAMON function, were installed sequentially in order to have a sequential base station ID. PEAMON will record the ID of each station and its corresponding signal strength to distinguish it from one floor to another.

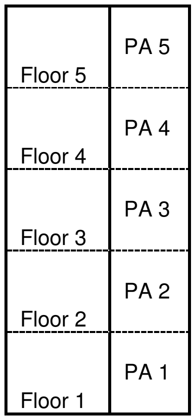

Figure 2. Sequential installations of PAs

The installation of PAs is illustrated in Figure 2 while example of base station ID is shown in Table 4. As can be seen from the table, each base station has a unique identification number making it simple to trace which floor the unit holder located. Interpreting the table would state that the unit holder was in Floor 1 from 9:10:00 until 9:10:15 and moves to Floor 5 at 9:10:30 and arrived to Floor 4 at 9:11.

The monitoring of the activities of the two workers inside the building assigned to transport the goods work in this way: they will write to the logbook their destination floors, number of offices intended for delivery and the number of goods going to deliver every time they leave the docking area located at the basement (B3) floor of the building. The PEAMON cannot record data while the holder is inside the elevator due to the absence of signal. However, PEAMON monitoring will resume as soon as the elevator opened up to the destination floor. Data will be recorded continuously every 15-seconds until they return again to the elevator.

Table 4. Example of station ID and signal strength

Time	PA1 (ID, SS)	PA2 (ID, SS)	PA3 (ID, SS)	PA4 (ID, SS)	PA5 (ID, SS)
9:10:00	1, 12				
9:10:15	1, 20				
9:10:30					5, 40
9:10:45					5, 25
9:11:00				4, 16	

3.2.3 Results of PEAMON monitoring

The result of PEAMON monitoring is presented in two ways. The first one is in the form of graph showing the routes of both workers starting from their first delivery in the morning until their last delivery at the end of the day. The second one is in the form of tables which clarify the individual route of the workers shown in the graph. Every single graph is composed of two supplemental tables.

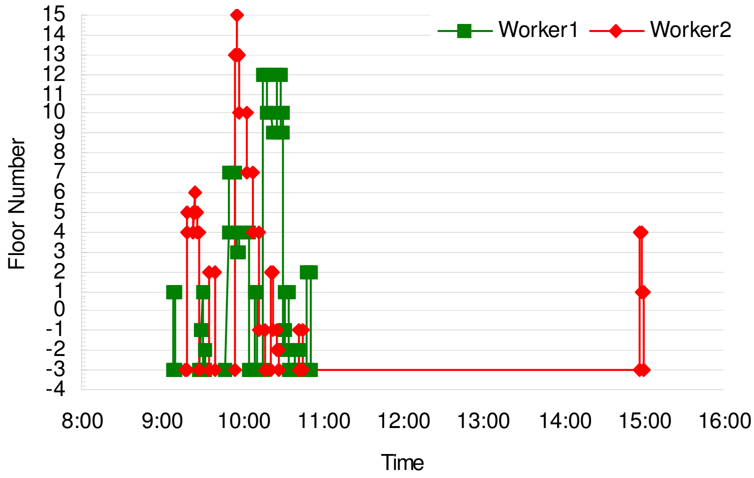

Figure 3. 2/19 PEAMON monitoring result

Table 5. Worker1's route

Time (Feb 19)	Route	Floor Location	No of office	No of delivery items	Destination	Time
9:00	B3⇒F1⇒B3				B3⇒F1	0:00:09
		1Floor	1	10	F1	0:01:51
					F1⇒B3	0:00:09
9:25	B3⇒B1⇒F1⇒B3				B3⇒B1	0:00:08
		B1	1	19	B1	0:01:25
					B1⇒F1	0:00:05
		1Floor	2	5	F1	0:00:21
					F1⇒B3	0:00:09
9:50	B3⇒F7⇒F4⇒F3⇒B3				B3⇒F7	0:02:43
		7Floor	2	9	F7	0:03:51
					F7⇒F4	0:00:09
		4Floor	1	2	F4	0:01:55
					F4⇒F3	0:00:05
		3Floor	1	8	F3	0:00:25
					F3⇒B3	0:07:50
10:15	B3⇒F12⇒F10⇒B3				B3⇒F12	0:00:25
		12Floor	1	1	F12	0:02:52
					F12⇒F10	0:00:08
		10Floor	1	2	F10	0:02:30
					F10⇒B3	0:13:15
10:40	B3⇒F2⇒B3				B3⇒F2	0:00:11
		2Floor	1	3	F2	0:02:19
					F2⇒B3	0:00:11

The monitoring result of PEAMON on the first day (Feb 19) of experiment is shown in Figure 3. The delivery activity started by Worker1 at 9 in the morning and followed shortly by Worker2 at 9:15. The first delivery stop of Worker1 was on Floor 1 and his last delivery was as early as 10:40 - brings three (3) pieces of goods to Floor 2. On the other hand, Worker2's first stop was on Floor 5 and ends his delivery after sending goods to Floors 4 and 1 at 2:55. The detail of the routes of Worker1 and Worker 2 is shown in Table 5 and 7 respectively.

Table 6. Worker2's route

Time (Feb 19)	Route	Floor Location	No of office	No of delivery items	Destination	Time
					B3⇒F5	0:01:13
9:15	B3⇒F5⇒B3	5Floor	1	12	F5	0:03:45
					F5⇒B3	0:04:15
					B3⇒F2	0:00:11
9:35	B3⇒F2⇒B3	2Floor	1	7	F2	0:04:49
					F2⇒B3	0:00:11
					B3⇒F15	0:01:57
		15Floor	1	1	F15	0:00:23
					F15⇒F10	0:00:37
		10Floor	1	3	F10	0:06:21
9:50	B3⇒F15⇒F10⇒F7⇒B1⇒B3				F10⇒F7	0:00:09
		7Floor	1	4	F7	0:04:53
					F7⇒B1	0:04:37
		B1	1	2	B1	0:03:38
					B1⇒B3	0:00:07
					B3⇒F2	0:00:11
		2Floor	2	6	F2	0:01:53
10:20	B3⇒F2⇒B2⇒B3				F2⇒B2	0:03:07
		B2	1	1	B2	0:00:55
					b2⇒B3	0:00:05
					B3⇒B1	0:00:07
10:40	B3⇒B1⇒B3	B1	1	11	B1	0:01:53
					B1⇒B3	0:00:07
					B3⇒F4	0:00:49
		4Floor	1	1	F4	0:00:51
14:55	B3⇒F4⇒F1⇒B3				F4⇒F1	0:00:09
		1Floor	1	1	F1	0:00:51
					F1⇒B3	0:00:09

The second day of PEAMON monitoring result is depicted in Figure 4. The route network of Worker1 started at 9:35 delivering goods to Basements 1, 2, and ends as early as around 11:54 after completing to deliver the goods for Basement 4. For the case of Worker2, his route network started at 9:45 and terminated at around 2:07 in the afternoon after having delivered the last goods to Floor 7. Although there were several

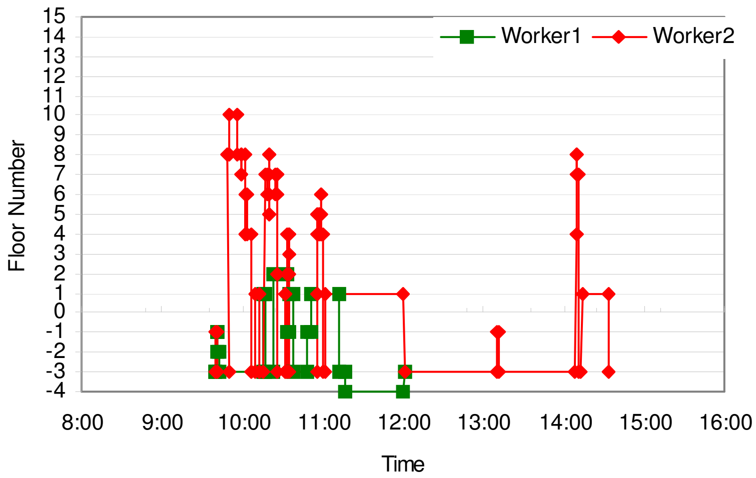

Figure 4. 2/20 PEAMON monitoring result

Table 7. Worker1's route

Time (Feb 20)	Route	Floor Location	No of office	No of delivery items	Destination	Time
9:35	B3⇒B1⇒B2⇒B3				B3⇒B1	0:00:07
		B1	1	24	B1	0:00:56
					B1⇒B2	0:00:05
		B2	1	1	B2	0:00:55
					B2⇒B3	0:00:05
9:55	B3⇒F1⇒B3				B3⇒F1	0:00:09
		1Floor	2	18	F1	0:01:21
					F1⇒B3	0:00:09
10:20	B3⇒F2⇒F1⇒B3				B3⇒F2	0:00:11
		2Floor	1	2	F2	0:10:37
					F2⇒F1	0:01:53
		1Floor	1	5	F1	0:02:06
					F1⇒B3	0:00:09
10:50	B3⇒B1⇒B3				B3⇒B1	0:00:08
		B1	1	7	B1	0:02:55
					B1⇒B3	0:20:20
11:10	B3⇒B4⇒B3				B3⇒B4	0:00:05
		B4	1	2	B4	0:44:25
					B4⇒B3	0:00:05

Table 8. Worker2's route

Time (Feb 20)	Route	Floor Location	No of office	No of delivery items	Destination	Time
9:45	B3⇒F10⇒F8⇒F6⇒F4⇒B3				B3⇒F10	0:00:49
		10Floor	1	1	F10	0:06:23
					F10⇒F8	0:00:07
		8Floor	1	4	F8	0:02:55
					F8⇒F6	0:03:35
		6Floor	1	1	F6	0:00:23
					F6⇒F4	0:00:07
		4Floor	2	5	F4	0:02:47
					F4⇒B3	0:00:13
10:15	B3⇒F7⇒B3				B3⇒F7	0:00:19
		7Floor	4	14	F7	0:02:25
					F7⇒B3	0:07:35
10:30	B3⇒F4⇒B3				B3⇒F4	0:00:41
		4Floor	1	1	F4	0:01:22
					F4⇒B3	0:00:38
13:10	B3⇒B1⇒B3				B3⇒B1	0:00:08
		B1	1	1	B1	0:01:52
					B1⇒B3	0:00:08
14:05	B3⇒F7⇒B3				B3⇒F7	0:01:13
		7Floor	1	1	F7	0:01:12
					F7⇒B3	0:00:18

rising of both networks of the two (2) workers as shown in the graph, it does not suggest that all the trips were made to deliver goods. The workers made several trips to other floors which when verified to the logbook do not show any delivery of goods involved.

The two tables complementing the routes shown in Figure 4 are Table 7 and 8. Table 7 explains the route network of Worker1 on the second day of the survey while Table 8 details the route of Worker2. As can be observed from Table 7 there are three (3) recorded time appear to be long enough to warrant a further clarification. First is the 10 minute and 37 second time spent in delivering goods at the 10:20 trip. A look at to PEAMON data, however, shows that this worker spend this whole time in Floor 2 without moving to other floors. This gives the impression that the worker was made to wait for some time before the receiver was available. The second case needs to be clarify because of the unusual longer time spend in delivering goods is the 10:50 trip. Data recorded by PEAMON shows that the worker after having delivered the goods for Basement 1, went to Floor 1 without carrying goods before finally returning to docking area. The third case, which raises concern due to spending more time than thought to be required, is the 11:10 trip. Shown in the PEAMON data that this worker spend the whole 44 minutes and 25 second in Basement 4. There must be unusual interruption which cause him to spend more time in facilitating this particular delivery.

Worker2's first trip chain as reflected in Table 8 revealed that he delivered goods continuously to Floor 10, Floor 8, Floor 6, and Floor 4. The longest delivery time was observed in the 10th floor, where one (1) piece of goods delivering took 6 min and 32 sec.

On the third day of experiment, PEAMON recorded data is illustrated in Figure 5. Worker1 made his first delivery to Floor 5 at 9:15 while Worker2 had delivered nine (9) pieces of goods to Floor 1 ten (10) minutes earlier. Both workers have their last departure from the docking area at 1:10 sharing the freight elevator. Although the same figure suggested that Worker2 still made one more departure at around 3 o'clock in the afternoon, records in the logbook shows that this trip was not related in transporting goods.

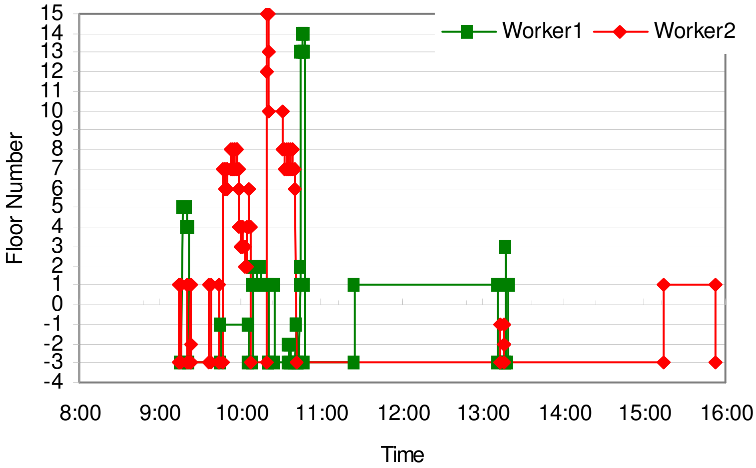

Figure 5. 2/21 PEAMON monitoring result

Table 9. Worker1's route

Time (Feb 21)	Route	Floor Location	No of office	No of delivery items	Destination	Time
					B3⇒F5	0:00:30
9:15	B3⇒F5⇒B3	5Floor	1	10	F5	0:03:40
					F5⇒B3	0:00:50
					B3⇒F2	0:00:11
		2Floor	1	4	F2	0:00:25
					F2⇒F1	0:00:05
		1Floor	1	2	F1	0:02:10
10:00	B3⇒F2⇒F1⇒F2⇒F1⇒B3				F1⇒F2	0:00:05
		2Floor	1	4	F2	0:03:55
					F2⇒F1	0:00:05
		1Floor	1	6	F1	0:05:06
					F1⇒B3	0:00:09
					F3⇒B1	0:00:08
10:40	B3⇒B1⇒B3	B1	1	2	B1	0:01:22
					B1⇒B3	0:00:08
					B3⇒F3	0:00:12
13:10	B3⇒F3⇒B3	3Floor	1	1	F3	0:00:48
					F3⇒B3	0:00:12

Table 10. Worker2's route

Time (Feb 21)	Route	Floor Location	No of office	No of delivery items	Destination	Time
					B3⇒F1	0:00:09
9:10	B3⇒F1⇒B3	1Floor	1	9	F1	0:00:51
					F1⇒B3	0:00:09
					B3⇒F 7	0:00:18
		7Floor	4	17	F7	0:00:25
					F7⇒F6	0:00:05
9:45	B3⇒F7⇒F6⇒F4⇒B3	6Floor	1	2	F6	0:00:25
					F6⇒F4	0:11:05
		4Floor	2	6	F4	0:00:25
					F4⇒B3	0:08:05
			1	1	B3⇒F15	0:00:55
		15Floor	1	1	F15	0:00:52
					F15⇒F10	0:00:38
		10Floor	1	3	F10	0:09:22
					F10⇒F8	0:00:08
10:15	B3⇒F15⇒F10⇒F8⇒F7⇒F6⇒B3	8Floor	1	1	F8	0:01:25
					F8⇒F7	0:00:05
		7Floor	1	1	F7	0:01:55
					F7⇒F6	0:05:35
		6Floor	1	1	F6	0:00:43
					F6⇒B3	0:00:17
					B3⇒B1	0:00:08
13:10	B3⇒B1⇒B3	B1	1	11	B1	0:02:25
					B1⇒B3	0:00:35

The details of each trip chain by the two workers graphed in Figure 5 are shown in Table 9 and 10. Worker1 actually visited and made delivery to seven (7) floors of which he spent the longest stay at Floor 6. On the other hand, Worker2 made delivery to eleven (11) floors visited 15 offices scattered to the floors building.

3.3 Summary result of the survey

The survey reveals several insights that can be useful in understanding the complexity of goods offloading chain. The arrived data averages and properties of elevator are shown in Table 11. Opening and closing time of elevator is 3.5 sec and 4.9 sec respectively. Furthermore, the elevator time for movement from one floor to next immediate floor (either up or down) is 5 sec. However, when the desired location is higher than that – say from first floor going to 5th floor – the elevator time from first floor to second floor is 5 second, while from second floor to 3rd floor is 2 second (Table 11).

Table 11. Averages observed from the survey

Floor	Elevator time	Ave time	Ave no of office	Ave no of goods	No of trip
15	30.0	0:00:37	1.0	1.0	2
14	28.5				
13	27.0				
12	25.5	0:02:52	1.0	1.0	1
11	24.0				
10	22.5	0:06:09	1.0	2.3	4
9	21.0				
8	19.5	0:02:10	1.0	2.5	2
7	18.0	0:02:27	2.2	7.7	6
6	16.5	0:00:30	1.0	1.3	3
5	15.0	0:03:43	1.0	11.0	2
4	13.5	0:01:28	1.4	3.0	5
3	12.0	0:00:36	1.0	5.0	2
2	10.5	0:04:00	1.2	4.3	6
1	9.0	0:01:50	1.3	7.0	8
-1	7.0	0:02:03	1.0	9.6	8
-2	5.0	0:00:55	1.0	1.0	2
-3	0.0	DOCKING AREA			
-4	5.0	0:44:25	1.0	2.0	1

The processing time for 13 goods (average per trip) at the docking are (B3) is 8 minutes. This time is refers to the moment the two workers work on the goods from the vehicle, sort out, divide the amount and identify each other's route up to their departure by the elevator. For instance, if the delivery is to be made at Floor 15, the computed time will looks like this- 8 minutes (processing time) plus 30 sec (elevator time) plus 8.4 sec (opening and closing time of elevator) plus 37 sec (average delivery time on that floor). This case assumes that the elevator is uninterrupted to the other floor and the first stop is the 15 floor.

The lack of available data concerning the sizes and weights of goods and the distance of offices from elevator make it difficult to explain the real cause on why some delivery time takes longer than the others do. Although logic might state that the amount of goods delivered and number of offices visited is directly proportional to the amount of time spent for delivery, it is also important to consider the distance of offices from the elevator. For instance, it would be difficult to explain on why the average delivery time to Floor 5 is shorter than say Floor 10 given that Floor 5 has more number of goods to be delivered. One possible explanation is perhaps the office visited in Floor 5 is closer to elevator than that of Floor 10.

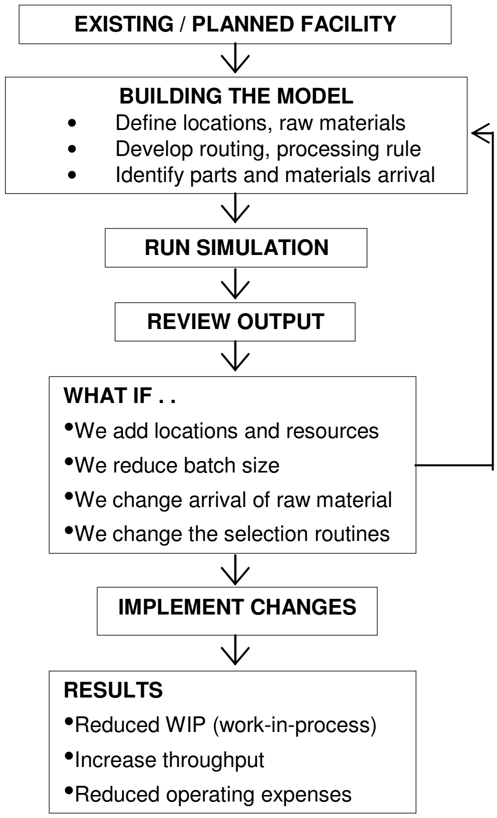

Figure 6. Process of building simulation model

The data of Basement 4 is consider irregular and was taken out during the computation for average delivery time to each floor which used as input data for simulation. There was a strong indication that there were interferences during the delivery to B4 and the time recorded did not reflect the actual delivery time.

4. MODELING

Several models are presented in this section depicting different scenarios. The actual counted data is applied to all the models and the effectiveness of having only one worker transporting goods has been modeled. In addition, the different interarrival times of truck trips such as 15 minutes and 30 minutes were also modeled separately to observe their effect. This is important to gained better understanding on the different variables that can influence the system's efficiency.

4.1 Process of building simulation model

Shown in Figure 6 is the process of building a simulation model in ProModel. This simulation software used five important elements to describe either existing or planned facility. Locations represent places where raw materials arrived or process. Raw material is anything that moves – for this study, the entity is goods. After having the two elements, the next step is to develop the routes used by entity at the same time connects one location to another. Processing rule is set to define what the modelers want the entity to do while at a location. Processing time and other ready commands can be issued in processing rule. The last element is the setting of arrival time and interarrival of raw materials. Several arrival distributions are available that can be applied. If the arrival or interarrival is complicated and cannot be easily set say 5 or 10 minutes, then StatFit statistical software included in ProModel can be used to identify which distribution best fit the data.

After completing these processes, the modelers may run the simulation and review the output. Modification can easily be made say adding or subtracting number of locations or resources. When the modelers finished the modifications, the simulation can be run repeatedly until desired result is attained.

4.2 Data Fitting

Table 12. Distributions Fit

Distribution	Rank	Acceptance	K-S test	A-D test
Inverse Gaussian (-3.35, 23.6, 40.1)	100	accept	Do not reject	Do not reject
Lognormal (-0.483, 2.93, 1.3)	99.9	accept	Do not reject	Do not reject
Pearson 5 (-7.7, 1.75, 39.4)	99.4	accept	Do not reject	Do not reject
Weibull (1, 0.682, 28.8)	98	accept	Do not reject	Do not reject
Exponential (1, 35.7)	96.2	accept	Do not reject	Do not reject
Erlang (1, 1, 35.7)	96.2	accept	Do not reject	Do not reject
Gamma (1, 1, 35.7)	96.2	accept	Do not reject	Do not reject
Pearson 6 (1, 102, 1.27, 4.23)	91.9	accept	Do not reject	Do not reject
Log-Logistic (1, 1.51, 23.4)	87	accept	Do not reject	Do not reject
Beta (1, 4.95e+6, 0.984, 1.23e+05)	73.4	accept	Do not reject	Do not reject
Pareto (1, 0.35)	7.37	accept	No fit	No fit
Triangular (0.951, 177, 0.986)	0.898	accept	Do not reject	reject
Uniform (1, 158)	0.0027	reject	reject	reject

Since the surveyed data do not follow any pattern, for instance 15 minutes interarrival, it is not possible to input a fix interarrival. To mitigate this difficulty, the perceived appropriate way to determine the best distribution that could represent the interarrival is the use of StatFit. This statistical software is available to ProModel simulation package. The collected data for arrival times of trucks in three-days were worked in Excel spreadsheet and plugged into the statistical software. After running the software, however, only the second day-data generated distributions fit and the two other arrival data were rejected due to insufficient of data point.

The suggested distributions to represent the interarrival times are shown in Table 12. Several distributions fitted the data which could be applied to interarrival of trucks trips. Normally, chi-square test is applied to see if the data came from a specific distribution. However, lack of adequate number of data points prevented from performing this test. Two other useful tests are Kolmogorov-Smirnov test (K-S test) and Anderson-Darling test (A-D test). Like the chi-square test, these tests are used to decide if the sample comes from a specific distribution. The A-D test is a modification of K-S test and gives more weight to the tails than does the K-S test. Result of K-S test, at .05 significance level, shows that only the Uniform distribution was rejected. On the other hand, the A-D test aside from rejecting the Uniform distribution also rejected the Triangular distribution. Both tests did not give value to the Pareto distribution. The lack of adequate data is seen as the main reason for the vague results of the tests. (Details of K-S test and A-D test were not shown for brevity).

Statistically, any of the remaining ten distributions could be applied for time intervals between trips. However, it is important to determine which distribution could provide an output that would reflect the real behavior of the system. Aside from applying all the accepted distribution to the simulation (figure 8 shows the result of exponential distribution), another method is by plotting the input data against the selected distribution as reflected in Figure 7. As shown in the figure, the shape of the data is the same as the plot of exponential distribution.

More than the methods employed to identify the fitted distribution to the data, literature often mention that exponential distribution often provides a good approximation of interarrival times in waiting line situations. This distribution is frequently used to represent the time between random occurrences, such as the time between arrivals at a specific location in a queuing model or the time between failures in a specific operation.

4.3 Description of the simulation model

The simulation models built were done using ProModel Version 4.1, a commercially available discrete event simulation package used for simulating manufacturing system. The entire process involved in transporting the goods is therefore modeled as a manufacturing network where each floor of the building, docking area, stock point are considered as locations. The goods coming in to the building is assigned as entity and the two workers and the trucks considered as resources. Elevator was not represented through resources due to perceived difficulty of handling it in the software since a resource (elevator for instance) cannot transport another resource (say worker 1). However, the network on which the worker/s travels was model the same function as the elevator.

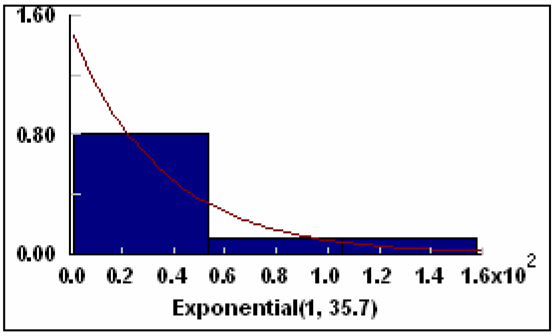

Figure 7. Fitted arrival distribution

For modeling convenience, certain assumptions were set:

- No distinction is made between types, sizes, and weights of cargo.
- From the floor where the delivery is to be made, it took 2 minutes and 24 seconds for worker/s to return to the elevator disregarding the number of offices and goods (this is obtained by getting the average of all floors' averages monitored by PEAMON).
- The required time for two workers to unload 13 goods, sort, and other necessary movement up to entering elevator is 8 minutes (average obtains from PEAMON monitoring).

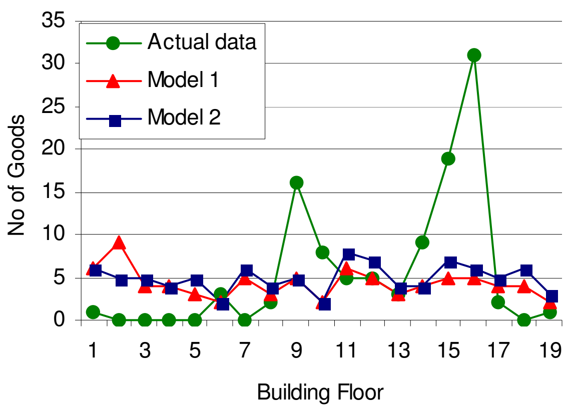

Figure 8. Actual data vs Models result

4.4 Properties of the models

All the models differ only to the variables number of workers and interarrival distribution. As shown in Table 13, in terms of the variable number of worker, only Model 1 is characterized by one worker and the rest models have two workers. This model is developed to test how it would fare if only one worker is employed with the same amount of goods coming and the same number of truck trip arrives. Model 2 represents the current operation system of the building establishment having two permanent workers stationed at the docking area. As discussed in the previous section, with regard to the interarrival distribution, the exponential distribution best fit the data. Two other models, Model 1 and 2, are developed to present alternatives to the present system.

Table 13. Properties of built models

Variables	Model 1	Model 2	Model 3	Model 4
No of worker	1	2	2	2
No of goods per arrival	13	13	13	13
No of trips per day	8	8	8	8
Interarrival distribution	exponential	exponential	15 min	30 min

$$\textbf{Utilization Percentage} = \frac{\text{Total Travel to Use Time + Total Time In Usage x 100}}{\text{Total Scheduled Time}} \qquad (1)$$

Equation 1 shows the computation process of utilization percentage (% utilization) of the workers. This is define as the percentage of time the resource spent traveling to be used, transporting or processing an entity, or servicing a location or other resource. Utilization percentage shows the total time of the workers involve in processing the goods. This value is the reflection of real time the workers work. The three (3) variables composing the equation are defined below:

Total Travel to Use Time is the time where the resource (workers) spent traveling to a location (floors, docking are, etc) to transport or process an entity (goods), or to service a location or other resource. It does not include any pick up time, but does include any blocked time.

Total Time in Usage is the total time the resource spent transporting or processing and entity (goods), or servicing a location or other resource. Includes any pick up and drop-off time as well as any blocked time while in use.

Total Schedule Time is the total number of hours the resources (workers) was schedules to be available.

The 100 multiplier in the equation is just a decimal conversion multiplier to make the percentage figure a whole number rather than a pure decimal value.

4.5 Results of the models

After running the simulation, the models' results shown in Table 14 were generated. The first variable means the average total time each goods spends in the system. This refers to the moment the goods arrived to the docking area (B3) until it was successfully transported to the receiver. The total time spend by the goods to the simulations is higher (61.82) in Model 1. This can be attributed to the assigning of one worker to facilitate the transport of goods. In contrast, Model 2 drastically reduced the time spent by the goods to the system due to the presence of two workers facilitating the goods. In this model, the two workers attended several delivery trucks since the interarrival is short before transporting the consolidated goods to the receivers. This model is behaving exactly the way the present system works wherein as shown in the result of the survey the interarrival between trips is very short. Since

Table 14. Results of built models

Variables	Model 1	Model 2	Model 3	Model 4
Ave min in system	61.82	36.73	52.12	20.25
Ave min in move logic	27.49	18.99	25.8	14.27
Ave min wait for pick up	5.8	4.26	3.58	2.84
Ave min blocked	28	13	5.58	3.12
% utilization	75	57 & 57	37 & 38	42 & 46

the intervals between trips in Model 3 are 15 minutes, the two workers are transporting the goods to the different recipients every time the delivery truck arrives. However, simulation result shows that it took more than 15 minutes to transport 13 pieces of goods to the recipients. This can be the reason why there is a long average time for the goods into the system (52.12). Model 4 is characterized by 30 minutes interarrival times of truck trips, which is more than enough time for the two workers to transport the 13 pieces of goods to the recipients and return to the docking area before another delivery truck arrives.

The second variable is the average time the goods spend traveling between floors and other locations, including any delays incurred. The results of Model 1 and Model 2 demonstrated the advantage of having two workers as the move logic of goods decreases significantly.

The third variable is the average time the goods spend waiting for pick up or waiting for another goods for consolidation before shipping. As the interarrival times of truck trips increases, the waiting time for resources (workers) decreases. This result is not surprising since when the intervals between trips are longer, the two workers have enough time to return to docking area after transporting the previous trip before another trip will arrive.

The fourth variable is the average time the goods spends waiting for the destination locations to have available space. The destination locations in the model were the docking area and the floors of the building. As the time intervals between trips increases, the less blocked time showed by the model. Model 1 have a high blockade time which demonstrated the inability of the single worker to free up the docking area and other locations before another truck trip is coming.

The utilization percentage, fifth variable of the model, of Model 1 is higher than of any other model. Model 2 and other models except Model 1 tend to suggest that the two workers are under utilized. The present system adopted by the management of the building establishment represented by Model 2 shows that the number of goods arriving and the number of truck trips are below to what the two workers might capable of delivering.

4.5.1 How long does it really take to deliver one truck trip?

A single truck trip is simulated carrying only 13 goods in order to observe the delivery time to the different floors using a) one worker and b) two workers. The difference between running the simulation having only 13 goods (1 truck trip) from running it having many goods and many truck trips is the former has no delay and therefore actual time to deliver all 13 goods can be observe. The worker/s usually consolidated the goods of several delivery trucks at the docking are before shipping it to the recipients. In this manner, it is not possible to observe the total time consumed for one truck trip.

The simulation result for the first case (one worker only) shows that it took about 26 minutes and 44 seconds from the moment the goods arrived before finally delivered to the receivers. On the other hand, if the two workers are working together, it took them about 15 minutes and 40 seconds to dispatch the 13 goods. These findings are suggesting that if the management decided to employ one worker, it would be appropriate to have an interval between trips of greater than the 26.44 minutes required to transport one trip of truck. In this manner, the moment another delivery truck arrives; the worker is already at the docking area. This will allow the delivery truck to move to another building without further delay. For the case of two workers assigned to transport the goods to the recipients, a higher than 15 minutes and 40 seconds will be suitable in order to attend the arriving delivery trucks immediately.

5. CONCLUSION

This study on a very simple elevator network used to transport goods gives several insights. First, it was proven that the new surveillance device system called PEAMON, aside for monitoring outdoor travel behavior, could also be applied in monitoring worker's activities inside a commercial or manufacturing building. This finding provided an alternative to the conventional way of data gathering which usually done by number of people equipped with timer. PEAMON data is free from human error or influence and therefore could provide more accurate. In most cases, data accuracy is a big factor to the outcome of a particular study. Second, the present system employed by the management of the building establishment, which hired two workers, seems under utilized. Terminating one worker, however, would prolong the delivery time and cause long queue of goods since this single worker could hardly attend to the very short time between arrivals. The early morning saw the arrivals of several truck vehicles that are not observing the 15 minutes time interval between trips. Distributing the arrivals of trucks to more long time, say 30 minutes would mitigate this problem however; this is very unlikely since most of the companies are rushing to move their supplies to the office in the early morning.

One way to increase the utilization percentage of the workers is to increase the frequency of truck trips and the volume of goods. It is important, however, to emphasize to these delivery trucks to observe a time pattern to avoid unnecessary delay that might be cause by the unscheduled trips. Increasing the frequency of trips would require the management of the building to convince all the tenants to participate to the delivery cooperative system. Simulation results show that even doubling the arrival volume of goods (13 at present) and vehicle trips (average is eight trips per day), the utilization percentage of these two workers would still stand at 70 and 72.

This paper is only part of Marunouchi study, which comprises several topics. While some significant insights were revealed, the paper is far from over. Included in the future activities to improve further this work is to calculate the travel time of goods from stock point to the docking area of the building/s and from the docking area to each destination floor of goods. The researchers also intend to include in the future work the effect of number of elevators to the movement of goods. This will naturally involves the experimentation of adding building floors and determining the appropriate number and properties of elevators.

ACKNOWLEDGMENT

The authors would like to extend their gratitude to Ministry of Land, Infrastructure and Transport for having us the data of Marunouchi. Appreciation also goes to Mr. Yoshitaka Komatsu, a master student for extending help in coding ProModel and Prof Saburo Tsuruta for his valuable advice on the same software.

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