SEARCH FOR SUITABLE URBAN FREIGHT DISTRIBUTION MEASURES: THE CASE OF HORIZONTAL AND VERTICAL COOPERATIVE DELIVERY SYSTEM

Nashreen G. Sinarimbo
Katahira & Engineers International
Taiko Building
4-2-16 Ginza, Chuo-ku
Tokyo, 104-0061 Japan
Fax: +81-3-3563-4055
E-mail: nash@katahira.com

Yoji Takahashi
Advanced Research Institute for Sciences and Humanities (ARISH)
Nihon University
1-2-1 Izimicho, Narashino City
Chiba, 275-8575 Japan
Fax: +81-90-6042-4329
E-mail: y.takahashi@catv29.ne.jp

Tetsuro Hyodo
Dept. of Logistics and Info. Engineering
Tokyo University of Marine Science & Tech.
2-1-6 Etchujima, Koto-ku
Tokyo, 135-8533 Japan
Fax: +81-3-5620-6492
E-mail: hyodo@kaiyodai.ac.jp

Abstract: Insufficient numbers of parking space and lack of (off) loading areas are some of common problems that driver of delivery trucks have to deal with. One way to address this problem is by increasing the utilization rate of the limited parking spaces by ensuring short parking time of trucks. Attaining this brief parking time, however, requires a shift from a traditional way of delivering goods to a policy-driven method. Traditional way presents a situation where the driver has to leave his truck and make his way to the floor of the building to make delivery. Although this method remains to be popular due to its simplicity, there exist methods that when carefully enforce would present sizeable benefits. One of these policies is by assigning workers inside the building to facilitate the (un)loading activities to free the driver immediately. This paper discusses implementation of cooperative delivery system and tries to produce a guideline regarding what CDS design is suitable depending on the characteristics of the CBD.

Key Words: *urban freight distribution, cooperative delivery system, urban goods movement*

1. INTRODUCTION

Ensuring efficient delivery of goods – i.e. safe and on time – lies to many segments of the delivery chain. Congestion may delay the truck, lack of parking space for truck may prolong the delay, and lack of sufficient number of freight elevator may further extend the delay. Facilities related to delivery of goods inside the building therefore require serious examination in the same manner as that of traffic congestion outside the building.

Delivery vehicles that cannot access the parking area inside the building would use any available space near the establishment to (un)load their goods. This behavior has substantial impact to the movement of other vehicles. The portion of road used by truck to park while delivering the goods reduces the capacity of the road thus the fluidity of traffic is affected.

Most buildings in the central business district have limited number of parking spaces allotted for trucks because of the prime importance of space. In a traditional way of delivering goods, normally, the driver would park the truck, unload the goods, call the freight elevator, and make his way to the floor where the recipient is located. Therefore, the truck exclusively use the parking space for the entire delivery chain until the driver gets back and move out of the building. Given this problem, one potential solution is to find a way to shorten the parking time of trucks which can be done by assigning workers at the parking area to assist the driver. This paper explores the possibility of such arrangement and then assessed the change of parking time and total delivery time.

The paper begins by reviewing related papers in management of the delivery system inside a building. Section 1 introduces the delivery chain while Section 2 is devoted to the review of significant papers in the delivery of goods. Along the review process, common problems in urban centers of moving goods were noted such as the difficulty of driver locating available parking space. Section 3 of the paper is devoted to cooperative delivery system while Section 4 provides brief presentation of the social experiment in Marunouchi district in Tokyo. Setting-up of simulation analysis and its result is found in Section 5. Section 6 attempts to produce a guideline on the application of CDS based on the characteristics of the CBD.

1.1 Urban Goods (Off) Loading Process

Iwao *et al* (2001) produces perhaps the most notable illustration of delivery process inside (unloading activity) the building (see Figure 1). The chain of this process is composed of six steps which start as soon as the delivery truck arrives. In the figure, the truck is parked in an on street (off) loading area which has the longest time of loading/unloading activity as compared to truck parked in a parking space located inside the building or beside the building (off-street) (Park et al, 1998). The obvious reason is its distance from the freight elevator located inside the building.

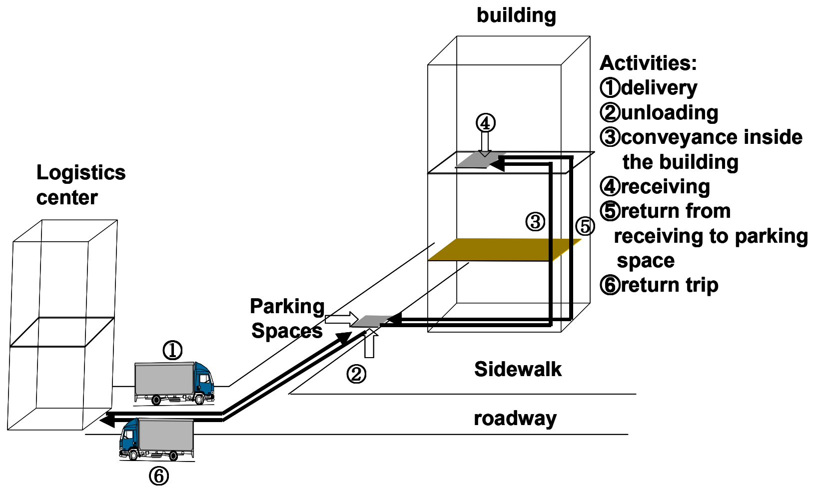


Figure 1. Delivery and unloading activities (source: Iwao et al, 2001)

1.2 Common Problems Related to (Off) Loading Activities

Problems of (off) loading activity range from lack of sufficient number of parking space to lack of freight elevator. In New York for instance, inadequate freight-handling facilities in the CBD were identified as the major barriers to freight mobility. Inadequate docks or receiving areas and insufficient freight elevators did not support the increasing number of freight deliveries, resulting in a significant amount of off-loading on the streets (Morris *et el*, 2001). Further, it is more difficult to deliver goods in the buildings in ancient cities where freight elevator usually does not exist. Under this condition, the goods carriers have to utilize the stair which naturally resulted to longer delivery time.

Parking spaces and freight elevators are two important elements that could determine the smoothness of the delivery activity. As the number of parking space increases, the probability that the waiting time of vehicle is short also increases. Parking time of vehicle on the other hand can be influenced by the availability of enough number of freight elevators. Truck drivers that do the delivery would find it fast to return to their truck if elevator is right waiting near the parking area.

Table 1. Problems and countermeasures of (off) loading activity

	Problems	Countermeasures
Trucks trip	Delayed delivery	Cooperative delivery, regulation of delivery time
	Reduction of travel speed	Provision of priority lanes for goods vehicle
	Mixing of passenger cars and freight vehicles	Traffic regulation, traffic imposition
Parking of goods vehicles	Parking congestion of passenger cars and freight vehicles at on-street parking facility	Time and spatial separation of vehicles at on-street parking facility
	Increase of illegal parking	Conduction of off-street parking facility (on-street parking facility regulation, parking charge discount)
		The reinforcement of the criterion on the planning of inside parking facility for goods vehicle
Loading/unloading	Competing people and goods	Spatial separation of people and goods
	Lack of conveyance paths	Design standards for conveyance path
	Lack of elevator for exclusive use of goods inside the building	Design standards of elevators for goods

Source: Park et al, 1998

Park *et al* (1998) has summarized the frequent encountered problems during the delivery of goods and its countermeasures (see Table 1). Congestion reduced the speed of trucks thus delay the delivery. This problem is compounded by the increasing number of vans used for delivery which propelled by the Just-in-time (JIT). It is argued that using vans instead of trucks will increase total traffic thus congestion.

The lack of parking spaces and (off) loading spaces for goods vehicles resulted to the rampant practice of occupying the spaces not intended for goods delivery. Although sometimes there are reserved spaces for vehicles delivering goods, it has been reported that in most cases, these are occupied by private cars and hence double parking occur. Protection of reserved places for goods vehicles therefore is necessary to ensure that right type of vehicles occupied the places.

Exclusive elevator for delivery is often inexistence or short in number affecting the entire chain of delivery – this means truck has to spend longer time in the (off) loading area.

2. IMPROVEMENT MEASURES FOR URBAN GOODS TRANSPORT

There are measures that can be applied to realize efficient delivery of goods in view of the difficulty faced by the sector (see Table 2). Although most of the measures listed are rather familiar, there are quite unconventional measures that have not been widely reported in literature such as time-sharing of both parking spaces and elevators, and consolidated delivery inside the building. Time-sharing is referring to allow the use of facilities intended for private cars (parking space) and passengers (elevator) to goods delivery during the determined off-peak periods in a day. This policy would increase the capacity of freight-handling facilities hence increase the fluidity of goods. Similarly, consolidating the goods intended for the same receiver would decrease the utilization of elevator. This scheme however might require some staff members permanently station at the (off) loading area to perform the consolidation. Some measures in Table 2 that are not very familiar are discussed further to make the paper more accessible.

(i) Establishment of Depot in the Inner City

As mentioned, protection to the city center of old towns by restraining access of delivery trucks is one of common reasons to erect a depot. Cities that were built even before the start of motorization were simply not suited to accommodate heavy vehicles and therefore were in need of other method to deliver the goods. This case has been witnessed in some European cities like Genoa in Italy. The depot then serves as consolidation area for goods that will be distributed to the final receivers by a truck that suits the environment of old town. In some cases, a staff in the depot would inform the recipient that a package has arrived and it can be delivered or be pick-up by the recipient.

Table 2. Improvement policy for urban goods movement

Type of Measures	**Hard**	▪ Establishment of depot in the inner city ▪ Increase of lane capacity ▪ Signal control improvement ▪ Provision of (off) loading and parking places ▪ Automatic conveyance material system inside the building
	Soft	▪ Consolidated delivery ▪ Efficient checking and sorting inside the building ▪ Cooperative delivery ▪ Time sharing of elevators ▪ Time-sharing of parking spaces ▪ Coordinated delivery inside the building

Source: Iwao et al, 2001

(ii) Signal Control Improvement

Signal control improvement has also been proven as an effective measure to improve the flow of traffic. This measure can be done by optimizing traffic signal timing plans, coordinating traffic signal control, and implementing adaptive signal control. Normally, results that can be attained for improving the signal control includes improvement of travel time, reduction of delays and stops of vehicles in the network.

(iii) Consolidated Delivery and Cooperative Delivery Systems

It appears obvious that there is a need to distinguish the difference between consolidated delivery and cooperative delivery. Literature tends to suggest that consolidation takes place when a cooperative delivery among companies is formed (Castro, 2002, Visser *et al*, 1999). Cooperative delivery change the form of urban delivery from independent private transport to consolidated transport that resulted to higher load factor and reduction of the number of trucks. It is worth to note thought that consolidated delivery can also be done by a single transport company having a multiple customers in an area.

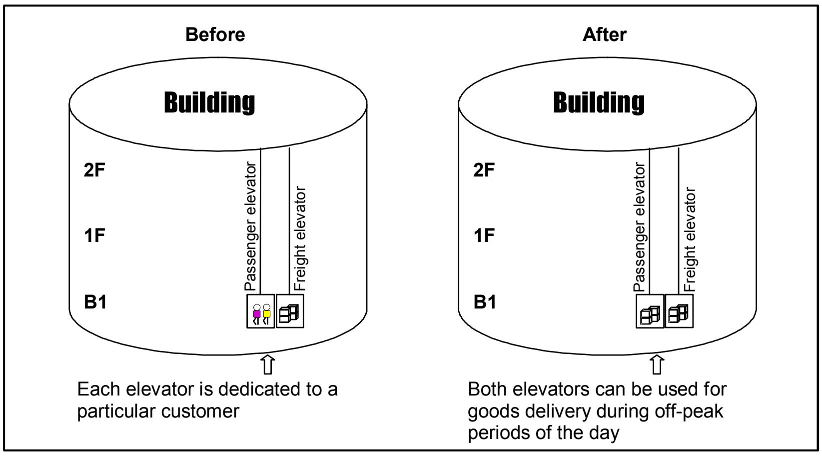


Figure 2. Time-sharing of elevators

(iv) Time Sharing of Elevators

Allowing freight carriers to use the passenger elevator during off-peak periods would increase their mobility (Figure 2). It should be noted however that some passenger elevators might not suit for freight use due to their configuration (i.e. more decorated such as glass wall which might be damaged during freight transport). In Japan, there was a reported case where 70% of trucks in a day arrived to a store before it opens thus they might be allowed to use elevators for passenger while the intended users are not yet at its peak (Iwao *et al*, 2001).

(v) Time Sharing of Parking Spaces

Parking management is a powerful tool to control the flow of traffic (Figure 3). This measure includes provision, control, regulation or restriction of parking space. Parking management can consist of actions that fall into six categories: on-street parking, off-street parking, fringe and corridor parking, pricing, enforcement and adjudication, and marketing.

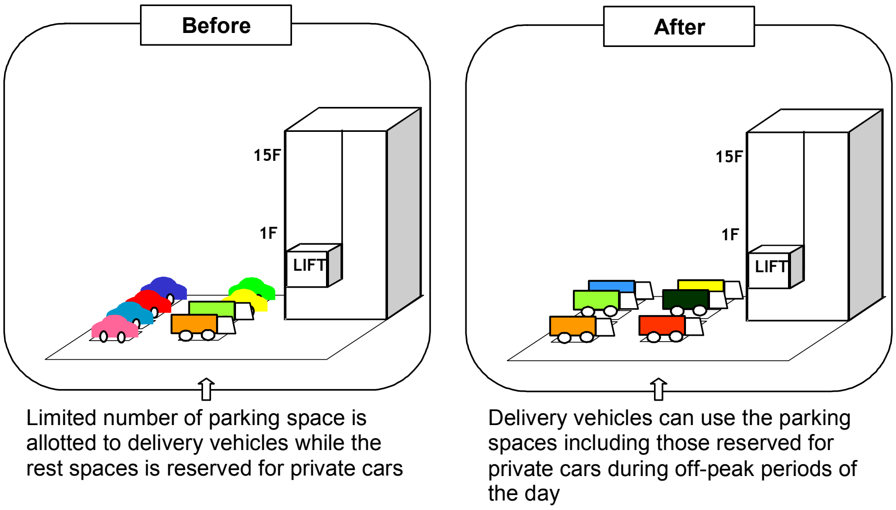


Figure 3. Time-sharing of parking spaces

Another parking management strategy that is being considers in many communities is the concept of shared parking. Shared parking in essence means that two or more land uses controlled by one or may owners can share the same parking space over the course of a day, week, or month. The basic premise for this strategy is shown in Figure 4 which indicates that different activities generate different temporal demands for parking which provide good opportunities for more efficient parking provisions.

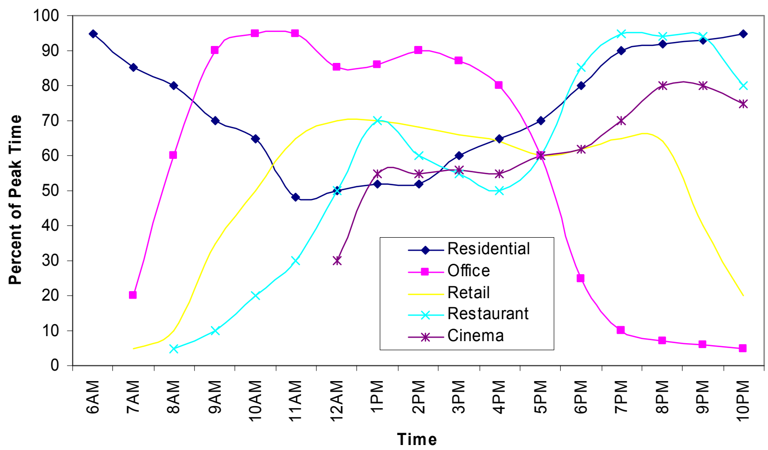


Figure 4. Parking Accumulation by Land Use by Time of the Day

Source: Meyer, M.D. (1997). A Toolbox for Alleviating Traffic Congestion and Enhancing Mobility, Institute of Transportation Engineers.

(vi) Coordinated Delivery Inside the Building

Organizing the goods after it was unloaded from the trucks would also bring some benefits such as utilization to the freight elevator would become more rationalize (Figure 5). This would remove unnecessary waiting time for staff delivering the goods since the elevator is hardly use.

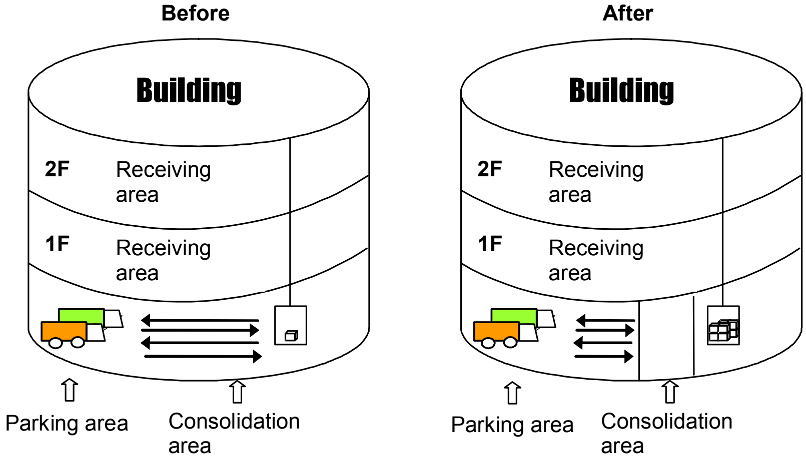
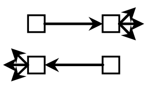
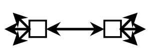
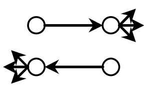
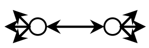
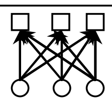
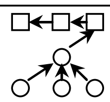
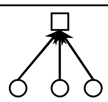
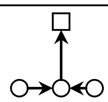
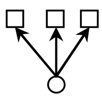
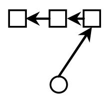


Figure 5. Coordinated delivery inside the building

3. COOPERATIVE DELIVERY SYSTEM

3.1 Different Models of Cooperative Delivery System and Its Application

There are many terminologies used to describe cooperative system; among them are cooperative freight transport system (CFTS) and voluntary cooperation. Yamada *et al* (1999) gives a clear definition of CFTS as systems in which a number of shippers or carriers jointly operate freight vehicles to reduce their costs for collecting and delivering goods and provide higher levels of service to their customers. Castro (2002) on the other hand stated that cooperative delivery is concerned with the promotion of change in the form of urban delivery, from independent private transport to consolidated transport using public carriers.

Type	Before Application	After Application	Remarks
Consolidated transport between shippers (Multiple shippers)			Mutual cooperation among shippers resulting to consolidated transport
Consolidated transport between carriers (Multiple carriers)			Mutual cooperation among carriers resulting to consolidated transport
Cooperative delivery (Multiple shippers, multiple carrier)			Shipments are consolidated at a distribution center, then delivered cooperatively to several outlets by routing
Cooperative delivery (Single shippers, multiple carrier)			Individual shipments are delivered to a designated carrier, which then performs consolidated delivery
Cooperative delivery (Multiple shippers, single carrier)			Carrier performs cooperative delivery to several outlets by routing

□ Shippers
○ Carrier

Figure 6. Different Models of Cooperative System

In essence, cooperative system is attained when two or more companies (either shippers or carriers) pool their resources and start coordinating their operation. Kuse (1999) provided what appears to be extensive list of cooperation delivery system models among the stakeholders in freight transport (Figure 6). The concept shown is very similar to the spoke-hub distribution paradigm.

3.2 Different Types of Design of Cooperative Delivery System

There are three ways to design a cooperative delivery system namely; (i) horizontal cooperative delivery system, (ii) vertical cooperative system, and (iii) combination of vertical and cooperative delivery system.

(i) Horizontal Cooperative Delivery System

Under the first design, trucks of different sizes and loads have to bring their cargoes to the stock point (SP) or depot for consolidation (Figure 7). Small trucks, normally non-polluting vehicles, will complete the delivery going to the customers. At the (off) loading area of the building, the driver would unload goods and deliver them to the recipients. Usual practices of cooperative delivery system follow certain time interval for delivery and assigned regular route. For instance, the Shinjuku Matenro cooperative has two delivery time in the morning (10:00 and 11:30) and one (13:50) in the afternoon and the route has been prepared to easily trace the delivery vehicles.

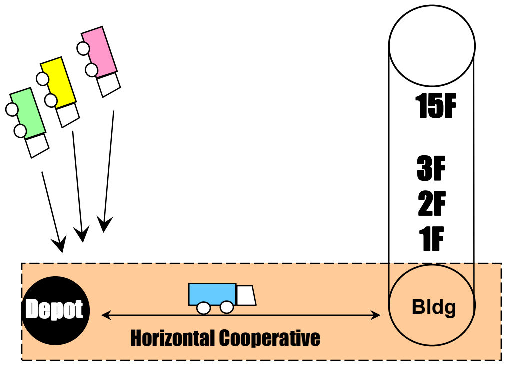


Figure 7. Design of Horizontal CDS

(ii) Vertical Cooperative Delivery System

Vertical cooperative delivery system on the other hand entails to assigning of staff at high rise buildings or establishment with high number of goods attracted. When the delivery trucks arrived, the staff would unload the goods and deliver them to the recipients. Under this system, trucks arrived without fix frequency and the goods are not consolidate due to the absent of Stock point where the consolidation can take place (Figure 8).

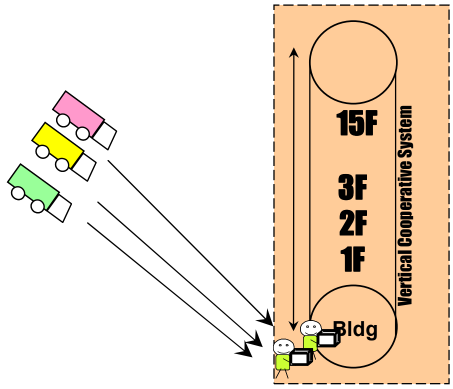


Figure 8. Design of Vertical CDS

(iii) Combination of Horizon and Vertical Cooperative Delivery System

The third design of cooperative delivery system which is the combination of horizontal and vertical cooperative system combined the functions of two systems resulting to comprehensive delivery system that has strong impact both on traffic and environment. Under this system, staff are usually stationed at each building covered by the joint delivery (Figure 9). The task of the staff is to free the driver from the difficulty of delivering goods going to the recipients. Instead, the staff would replace this role from the driver. After the truck docked-in at the (off) loading area of the building, the staff would unload the goods and the driver would move immediately to the next delivery destination. This procedure allows

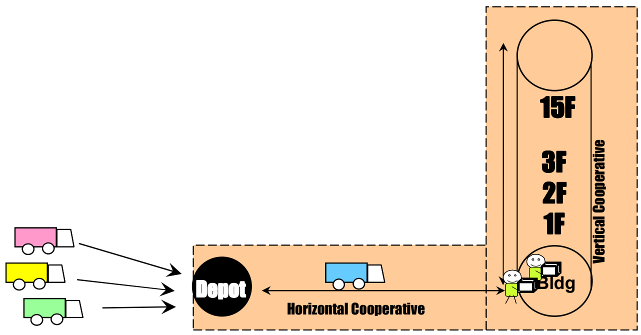


Figure 9. Design of combination of Horizontal and Vertical CDS

limited parking time of the truck and the delivery is faster. The familiarity of the staff to the layout of the building contributes to speedy delivery. The cooperative delivery system that was adopted in Marunouchi district falls under this category of design of cooperative delivery system.

4. SOCIAL EXPERIMENT AT MARUNOUCHID DISTRICT

4.1 Review of Building Use and Trip Attraction

Land use has tremendous effect to the movements of trucks. Table 3 shows that space used for commercial purposes, i.e. either shop or restaurant, has large number of attracted trips. Moreover, it appears that pulling strength of CBD in terms of attracted trips does not determine by country's level of economic development. Trip attractions of space for commercial use in Manila, a capital city of a developing country, are even stronger than the trip attractions in Ginza although smaller than that of Marunouchi district, both of Japan. It should be noted that the data of Manila and Marunouchi is taken from the survey done by the authors in 2005 and 2002 respectively.

Table 3. Trip attraction of space use in a building per 1000 sq meter

CBD name	GLA (m^2)*	Number of trips	Office	Shops and restaurants
Tokyo (Marunouchi district)	153801	442	2.6	14.1
Tokyo (Ginza district)	218 shops	-	2.9	10.64
Manila	471158	3858	-	12.03*

*Note: *GLA means Gross Leasable Space; **data is taken from shopping centers*

4.2 Application of Measures to Improve Goods Delivery

Four policies from Table 2 were seen adopted in the social experiment in the Marunouchi, Tokyo in 2002 – (i) establishment of depot, (ii) provision of off/loading and parking places, (iii) cooperative delivery, and (iv) consolidated delivery inside the building. The social experiment is reported in length by Takahashi *et al* (2004). Although there exist number of papers regarding the experiment itself, this is the first time that an attempt to analyze all different designs of CDS is made.

Freight elevator supports all the building covered by the experiment and designated parking spaces for delivery vehicles are also available (see Table 4). The number of trips and goods found in the table is recorded prior to experiment. This was done to observe the natural process of performing delivery activity and to determine the severity of truck's traffic.

At the (un)loading area inside the four (4) buildings joined the social experiment, two staff members are permanently station to assist the drivers of delivery trucks. After unloading the goods, the truck would leave and move to the next building and the same process is repeated. This arrangement, however, is not available to those who did not participate to the social experiment.

The effect of this scheme reduced the parking time of each truck from 15 minutes to 2.35 minutes. This reduction to the parking time of trucks was mainly credited to the presence of two staff which handles the goods once the truck entered the docking area. The usual responsibility of the driver, that is to deliver the goods to the final recipients, has been passed to the staff. This arrangement allows the driver to bring out the truck to the next delivery destinations.

Table 4. Properties of the four buildings

Building		Furukawa & Yaesu	Mitsubishi Jyukou	Mitsubishi Shouji	Mitsubishi
No of floor		9	10	15	15
No of freight elevator		1	1	1	1
No of staff member at unloading area		2	2	2	2
No of parking space		4	4	4	4
Gross floor (m^2)		70016	45985	55259	62906
Leasable space (LS) (m^2)		43628	31861	37829	40484
Percentage of LS		62%	69%	68%	64%
Office space (OS) (m^2)		41080	30477	37829	40248
Percentage (OS)		94%	96%	100%	99%
Shops & Restaurants (SR) (m^2)		2547	1414	0	236
Percentage (SR)		6%	4%	0%	1%
Trips per day	Office	84	74	132	93
	Shops & Restaurants	18	18	0	23
	Total	102	92	132	116
No of freight per day	Office	144	184	772	271
	Shops & Restaurants	68	100	0	185
	Total	212	284	772	456

5. COMPARISON OF TIME SAVED FROM THE DIFFERENT DESIGNS OF CDS

5.1 Introduction

In order to evaluate which CDS design is to be applied as a management measure for freight transport in the CBD, a simulation analysis is conducted to the Marunouchi district. At first, all the 15-buildings were assumed to have the same number of story which is 15. The number of story is then increased to 20, 30, and 40. The simulation and analysis process compares the average waiting time of trucks between with and without CDS schemes.

In this section of the study, four cases is compared; *1) without CDS, 2) Vertical CDS, 3) Horizontal CDS, 3) combination of Vertical and Horizontal CDS*.

5.2 Data requirements

The Marunouchi building was taken as model to estimate the likely GLA of the building area when it reaches 40-story. At present, no building exceeded 40-story. Marunouchi building being the tallest has 37-story. With that consideration, the likely configuration of the building in the area is shown in Table 5. As mentioned, the area is more of an office-oriented CBD where around 97% of building space is dedicated for office use.

Table 5. Properties of the buildings

Building story	GLA (sq. m.)	Parking space	Freight elevator	Space usage		Trip attraction per 1,000 sq. m.	
				Office	Shops and Restaurants	Office	Shops and Restaurants
15 story	42,162	4	2	97	3	2.6	14.1
20 story	56,216	5	3	97	3	2.6	14.1
30 story	84,324	6	4	97	3	2.6	14.1
40 story	112,432	8	5	97	3	2.6	14.1

Note: Trip attraction is based on the survey in Marunouchi district in 2002.

The estimated number of trips based on the trip attraction in Table 5 is available in Table 6. The number shown is total delivery trips but since each truck would make two deliveries, the total number of trucks entering the district is therefore half of the total trips. For instance, the total number of trucks that would enter the CBD when all the buildings are 15-story is 900 trucks.

Table 6. Number of trips without CDS and under Vertical CDS

Building story	Number of trips 8:00 - 9:30	9:30 - 12:00	12:00 - 17:00	Total	Total trips to 15-bldgs
15 story	29	42	49	120	1800
20 story	38	56	65	160	2400
30 story	58	84	98	240	3600
40 story	77	112	131	320	4800

Note: Average goods per delivery to one building is 4. Survey results show that every truck had made two stops for each delivery, the total number of goods per truck therefore is 8.

Without CDS scheme and *Vertical CDS scheme* have the same pattern of truck trips. The only difference between them is that under the *Vertical CDS*, there are staff inside the building that would help the driver unloads the goods. In essence, there is no depot and goods consolidation under the Vertical CDS.

Table 7. Number of trips and goods under Horizontal CDS and combination of Horizontal and Vertical CDS

Building	Number of trips				Number of goods			
story	8:00 - 9:30	9:30 - 12:00	12:00 - 17:00	Total	8:00 - 9:30	9:30 - 12:00	12:00 - 17:00	Total
15 story	6 (19)	5 (34)	5 (39)	16	115	168	196	479
20 story	6 (26)	5 (45)	5 (52)	16	153	224	262	639
30 story	6 (38)	5 (67)	5 (79)	16	230	336	393	959
40 story	6 (51)	5 (90)	6 (87)	18	307	448	524	1279

Note: Figures in the parenthesis are number of goods per delivery to one building. Since CDS truck would make two stops for each delivery, the total number of goods per truck is therefore double of that number.

Horizontal CDS scheme and the combination of Horizontal and Vertical CDS scheme have the same pattern of truck trips (Table 7). The only component that separates them is the availability of staff inside the building for the combination of Horizontal and Vertical CDS. Horizontal CDS relies to the ability of the driver to unload all the consolidated goods. Further, there is a depot where goods are consolidated under these two schemes.

5.3 Setting-up the Arrival Distribution of Freight Vehicles

The arrival of freight vehicles for the case of CDS follows the format set by the Committee designed the social experiment – 15 minutes interval from 8:00 – 9:30; 30 minutes interval from 9:30 – 12:00 and; 60 minutes interval from 12:00 – 17:00.

For the case of normal form of delivery, the distribution pattern of the recorded arrival time of the one-day survey is followed (Figure 10). The

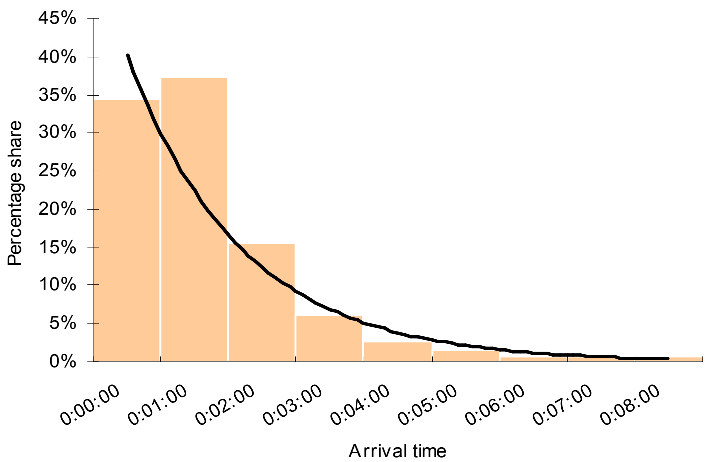


Figure 10. Distribution pattern

arrival of freight vehicle follows exponential curve as reflected in the same figure. Close to 35 percent of trips has equal or less than 1-minute interval while close to 40 percent has 1 to 2 minutes interval. The said distribution is used as input data that determines the arriving pattern of freight vehicle in the simulation. For the case of CDS, however, a fixed interval between trips is used.

5.4 Properties of the Simulation Model

The simulation analysis of the study was entirely designed in the commercially available manufacturing simulation software SIMUL8. This software combines the graphical interface and spatial simulation. The works on the principle of drawing from different spatial components of study area composed of organization/establishment to be analyzed. Data specifying the dimension of the organization/establishment or that would define the behaviors of the workers or vehicles can be done by filling in numerical information ready available.

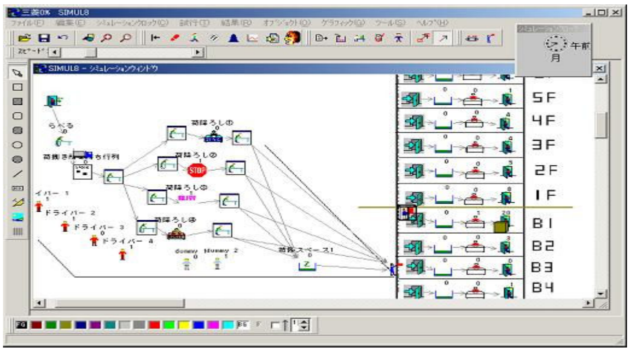


Figure 11. Screenshot of the simulation model

Table 8. Properties of the simulation model

	Without CDS	With CDS
Unloading time	19.8 sec	19.8 sec
Delivery time	27 sec	27 sec
Elevator time per floor	5 sec	5 sec
Elevator's maximum capacity	20	20
No of workers	0	Based on the number of elevator plus 1 staff

The drawing of simulation model is done by clicking buttons and dragging the objects to their location. In the study's model, first created were those fixed objects such as Stock point, loading dock, floors of the building. Routes between these objects were made by clicking the arrow and entering appropriate figure say speed, distance and other dimensions that characterize the behaviors of elements of the model. On the other hand, controlling the arrival of freight vehicle is made by selecting appropriate distribution built-in the software. Working environment of the software and the screenshot of the study's model is shown in Figure 11.

The properties of simulation model are shown in Table 8. These figures were obtained during the social experiment. The average unloading time per freight from the vehicle up to the elevator is 19.8 seconds while it took 27 seconds to deliver each good from the elevator up to the receiver. It can be observed that the delivery time is longer as compared with the unloading process since the delivery staff sometimes has to wait for the receiver.

During the experiment, it was recognized that the two staff assigned at each building were not able to hold the incoming freight to the buildings where attraction of trips are high. Further, the 15-minute interval between trips is too close for the two staff members to deliver the first trip and clear the (off) loading area before another trip arrives. In this paper, the number of staff stationed at a building was based on the number of elevator. One additional staff is provided, aside from the mentioned number of staff, designed to be permanently station at the loading / unloading area to help unload the freight from the vehicle with the driver and sign the document confirming that the freight were delivered. This process would allow the driver to move immediately making the loading / unloading space available for another income trips.

5.5 Simulation Results

The average waiting time of trucks is considerably low when the building has 15-story to all the schemes (Figure 12). Even without any form of CDS, the average waiting time is merely 2.27 minutes. There was also a small waiting time under the Vertical CDS at 0.7 minute. This can be attributed to the high number of trucks in the morning and limited number of space where trucks could park while waiting for the assistance of the staff inside the building.

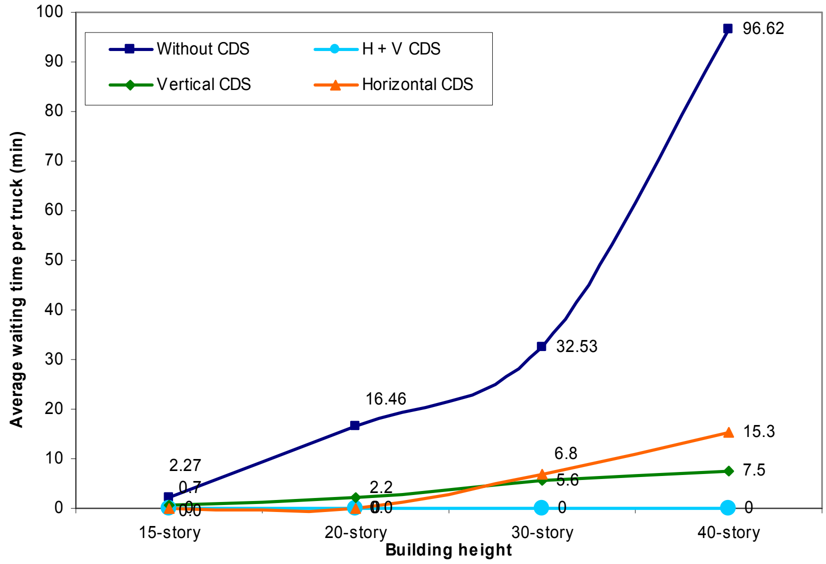


Figure 12. Average waiting time of trucks per CDS design

In this section of the study, the term "distribution time" will be used to describe time derived from delivery, unloading, waiting time for parking, labor time at stock point (SP), and vertical delivery. The summary of distribution time from Table 9, Table 10, and Table 11 is shown in Table 12. For a district which has an average height of 15-story buildings, Horizontal CDS has the lowest delivery time followed by without CDS scheme. The reason that the combination of Horizontal and Vertical CDS have high distribution time is because of the substantial time by staff inside the building. This is a large time that can not be easily offset through reduction of delivery time and waiting time.

Table 9. Comparison of *Without CDS scheme* and *Combination of Horizontal and Vertical CDS scheme*

Variables	Computation process	Without CDS	Computation process	H + V CDS	Difference
a. 15-story					
Delivery time	898 trucks x 5.34 min	4,796	120 trucks x 5.34 min	641	4155
Unloading time	7185 goods x 0.33 min	2,371	7185 goods x 0.33	2,371	0
Waiting time for parking	1796 trucks X 2.27 min	4,077	240 trucks X 0 min	-	4077
Labor time at SP	No SP	-	1 min/goods X 7192 goods	7,192	-7192
Vertical Delivery time	7185 goods x 1 min	7,185	45 staff x 421 min	18,945	-11760
Total		18,430		29,148	-10719
b. 20-story					
Delivery time	1198 trucks x 5.34 min	6,398	120 trucks x 5.34 min	641	5757
Unloading time	9585 goods x 0.33	3,163	9585 goods x 0.33	3,163	0
Waiting time for parking	2396 trucks X 16.46 min	39,442	240 trucks X 0 min	-	39442
Labor time at SP	No SP	-	1 min/goods X 9589 goods	9,589	-9589
Vertical Delivery time	9585 goods x 1 min	9,585	60 staff x 437 min	26,220	-16635
Total		58,588		39,613	18976

c. 30-story					
Delivery time	1798 trucks x 5.34 min	9,602	120 trucks x 5.34 min	641	8961
Unloading time	14385 goods x 0.33	4,747	14385 goods x 0.33	4,747	0
Waiting time for parking	3596 trucks X 32.53 min	116,986	240 trucks X 0 min	-	116986
Labor time at SP	No SP	-	1 min/goods X 14383 goods	14,383	-14383
Vertical Delivery time	14385 goods x 1 min	14,385	75 staff x 437 min	32,775	-18390
Total		145,720		52,546	93174
d. 40-story					
Delivery time	2398 trucks x 5.34 min	12,806	135 trucks x 5.34 min	721	12085
Unloading time	19185 goods x 0.33	6,331	19185 goods x 0.33	6,331	0
Waiting time for parking	4796 trucks X 96.62 min	463,414	270 trucks X 0 min	-	463414
Labor time at SP	No SP	-	1 min/goods X 9589 goods	19,178	-19178
Vertical Delivery time	19185 goods x 1 min	19,185	90 staff x 443 min	39,870	-20685
Total		501,736		66,100	435636

Note: 5.34 minute is the average time a truck has to spend in the district to deliver goods (computed by getting average distance and truck's speed in the district) while 0.33 minute and 1 minute (for labor time at SP and vertical delivery) are derived from survey data. The number of staff is equal to total number of freight elevator plus one additional staff while waiting time of trucks and staff's working time (vertical delivery) are derived from simulation result (Details discussion can't be done due to page limitation).

Table 10. Comparison of *Without CDS* scheme and *Vertical CDS scheme*

Variables	Computation process	Without CDS	Computation process	Vertical CDS	Difference
a. 15-story					
Delivery time	898 trucks x 5.34 min	4,796	898 trucks x 5.34 min	4,796	
Unloading time	7185 goods x 0.33 min	2,371	7185 goods x 0.33 min	2,371	0
Waiting time for parking	1796 trucks X 2.27 min	4,077	1796 trucks X 0.7 min	1,257.38	2820
Labor time at SP	No SP	-	No SP	0	0
Vertical Delivery time	7185 goods x 1 min	7,185	45 staff x 432 min	17,280	-10095
Total		18,430		25,704	-7,275
b. 20-story					
Delivery time	1198 trucks x 5.34 min	6,398	1198 trucks x 5.34 min	6,397	1
Unloading time	9585 goods x 0.33	3,163	9585 goods x 0.33	3,163	0
Waiting time for parking	2396 trucks X 16.46 min	39,442	2396 trucks X 2.2 min	5,271.75	34171
Labor time at SP	No SP	-	No SP	0	0
Vertical Delivery time	9585 goods x 1 min	9,585	60 staff x 475 min	28,500	-18915
Total		58,588		43,332	15,256
c. 30-story					
Delivery time	1798 trucks x 5.34 min	9,602	1798 trucks x 5.34 min	9,602	0
Unloading time	14385 goods x 0.33	4,747	14385 goods x 0.33	4,747	0
Waiting time for parking	3596 trucks X 32.53 min	116,986	1798 trucks X 5.6 min	20,139.00	10642
Labor time at SP	No SP	-	No SP	0	0
Vertical Delivery time	14385 goods x 1 min	14,385	75 staff x 470 min	35,250	0
Total		145,720		69,738	75,982
d. 40-story					
Delivery time	2398 trucks x 5.34 min	12,806	2398 trucks x 5.34 min	26,408	0
Unloading time	19185 goods x 0.33	6,331	19185 goods x 0.33	6,527.80	0
Waiting time for parking	4796 trucks X 21 min	463,414	2398 trucks X 7.5 min	35,971.88	10642
Labor time at SP	No SP	-	No SP	0	0
Vertical Delivery time	19185 goods x 1 min	19,185	90 staff x 470 min	42,300	0
Total		501,736		111,208	390,528

Table 11 Comparison of *Without CDS* scheme and *Horizontal CDS scheme*

Variables	Computation process	Without CDS	Computation process	Horizontal CDS	Difference
a. 15-story					
Delivery time	898 trucks x 5.34 min	4,796	120 trucks x 5.34 min	641	4155
Unloading time	7185 goods x 0.33 min	2,371	7185 goods x 0.33	2,371	0
Waiting time for parking	1796 trucks X 2.27 min	4,077	240 trucks X 0 min	-	4077
Labor time at SP	No SP	-	1 min/goods X 7192 goods	7,192	-7192
Vertical Delivery time	7185 goods x 1 min	7,185	7185 goods x 1 min	7,185	0
Total		18,430		17,388	1041
b. 20-story					
Delivery time	1198 trucks x 5.34 min	6,398	120 trucks x 5.34 min	641	5757
Unloading time	9585 goods x 0.33	3,163	9585 goods x 0.33	3,163	0
Waiting time for parking	2396 trucks X 16.46 min	39,442	240 trucks X 6.8 min	-	39442
Labor time at SP	No SP	-	1 min/goods X 9589 goods	9,589	-9589
Vertical Delivery time	9585 goods x 1 min	9,585	9585 goods x 1 min	9,585	0
Total		58,588		22,978	35611
c. 30-story					
Delivery time	1798 trucks x 5.34 min	9,602	120 trucks x 5.34 min	641	8961
Unloading time	14385 goods x 0.33	4,747	14385 goods x 0.33	4,747	0
Waiting time for parking	3596 trucks X 32.53 min	116,986	240 trucks X 6.8 min	1,632	115354
Labor time at SP	No SP		1 min/goods X 14383 goods	14,383	-14383
Vertical Delivery time	14385 goods x 1 min	14,385	14385 goods x 1 min	14,385	0
Total		145,720		35,788	109932
d. 40-story					
Delivery time	2398 trucks x 5.34 min	12,806	135 trucks x 5.34 min	721	12085
Unloading time	19185 goods x 0.33	6,331	19185 goods x 0.33	6,331	0
Waiting time for parking	4796 trucks X 96.62 min	463,414	270 trucks X 15.3 min	4,131	459283
Labor time at SP	No SP	-	1 min/goods X 9589 goods	19,178	-19178
Vertical Delivery time	19185 goods x 1 min	19,185	19185 goods x 1 min	19,185	0
Total		501,736		49,546	452190

For a CBD with an average of 20-story buildings, Horizontal CDS still has the lowest delivery time. This is followed by the combination of Horizontal and Vertical CDS and Vertical CDS comes third. One notable observation is that all the CDS design have lower distribution time as compared to the present scheme (without CDS).

For a high density CBD with an average building height of 30-story, still the Horizontal CDS produces the smallest distribution time. Although it has the lowest distribution, it should also be noted that it has the highest waiting time of trucks among the 3 CDS schemes at 6.8 minutes (Figure 12). The order of distribution time remain the same even after the height of the buildings in the CBD is increased to 40-story – Horizontal CDS being the scheme having the lowest distribution time. Waiting time of this CDS design however increases to 15.3 while Vertical CDS increases to 7.5 minutes (Figure 12). The combination of Horizontal and Vertical CDS has not record waiting time from different CBD densities.

Table 12. Total delivery time from each scheme

Building story	TOTAL TIME (min)			
	Without CDS	H + V CDS	Horizontal CDS	Vertical CDS
15-story	(2) 18,430	(4) 29,148	(1) 17,388	(3) 25,704
20-story	(4) 58,588	(2) 39,613	(1) 22,978	(3) 43,332
30-story	(4) 145,720	(2) 52,546	(1) 35,788	(3) 69,738
40-story	(4) 501,736	(2) 66,100	(1) 49,546	(3) 111,208

Note: Figure in the parenthesis is rank of each scheme, 1 being the scheme having the lowest distribution time

6. CONCLUSION AND RECOMMENDATION

From the social point of view, i.e. reduction of environmental emissions and other negative impact of trucks, any CDS scheme is desirable. Reduced number of trucks would mean few sources of emissions, vibration, accident and other negative externalities born out of truck's presence. There is no change to the number of trucks under Vertical CDS since there is no consolidation of goods however there is benefits in the form of reduced waiting time.

However, when other components of distribution system are considered such as labor time at depot and unloading time, each CDS has its own strength. For instance, when a CBD is low density, i.e.15-story buildings, Horizontal CDS is the most suitable owing to the 6% time saved (Figure 13). Adopting any of the other two CDS would increase distribution time which can be interpreted as increase to distribution cost as shown by the negative position of the curve.

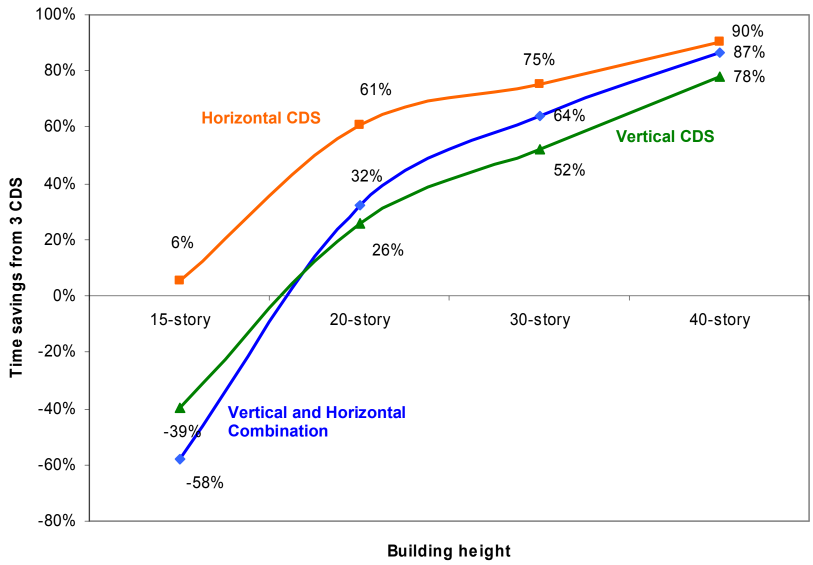


Figure 13. Time saved from three types of CDS for an office-oriented CBD

The positive effect of all the CDS begins when the building height reaches 20-story. This means that the building administration has more options of which CDS to adopt knowing that this would not necessarily increase the distribution cost. The time saves from the combination of Horizontal and Vertical CDS is notable since under the CBD with 15-story buildings, it has the largest loss.

It must be noted that the analysis is performed to an office-oriented CBD and therefore there might be changes to the pattern of time saves from the different CBD designs. Based on this result however, it can be theorized that significant changes of building use from office to commercial (i.e. shops and restaurants) would put the combination of Horizontal and Vertical CDS into strong position as the most effective measure. This theory have two grounds; 1) there would be substantial increase to the number of trucks and gained from delivery time alone would be tremendous and 2) there would be a long waiting time of trucks which could be removed when Horizontal and Vertical CDS is adopted. Of course adopting the Horizontal CDS would have also bring tremendous reduction of truck trips however without the assistance of staff inside the building, it would be difficult for the driver alone to deliver the consolidated goods. This situation would significantly increase delays to other CDS trucks.

The highlight of the paper is the identification of suitable CDS design depending on the building density of the CBD. It was found out that Horizontal CDS is the only design suitable for low density CBD in view of distribution time. Adopting any of the two other CDS designs, i.e. the combination of Horizontal and Vertical CDS and Vertical CDS, would bring increase to the distribution time and therefore would increase the distribution cost. However, when the building density increases and each building reaches 20-story, all the 3 CDS designs bring enormous benefits in the form of time saved. These findings would be useful guidelines in selecting which CDS design is adopted and when it is adopted based on the characteristics of the CBD.

REFERENCES

1. Ashida, N. et al (2002). A study on the improvement of home delivery systems and the effect of introudincg a new measure in a concentrated high-rise residential area. **City Logistics II**. Institute of Systems Science Research, Japan.
2. Iwao, E. and Kuse, H. (2001) Traffic and Environmental Impact Analysis of Large-scale Facilities in the Commercial Business District. **Journal of Eastern Asia Society for Transportation Studies,** Vol. 4, No.1, 523-535.
3. Meyer, M.D. (1997). A Toolbox for Alleviating Traffic Congestion and Enhancing Mobility, **Institute of Transportation Engineers**.
4. Morris, A. and Kornhhi Auser, A (2001). Relationship of Freight Facilities in Central Business District Office Buildings to Truck Traffic. **Transportation Research Record 1707**, Paper No. 00-0197.TRB, National Research Council, Washington, D.C.
5. Park, S. et al (1998). A Simulation Analysis on Loading/Unloading and Pick-Up/Delivery Activities for Efficient Goods Movement at the CBD in Japan, No. 199, **8th World Conference on Transport Research**, Antwerp, Belgium.
6. Takahashi, Y., Sinarimbo, N. and Hyodo, T. (2004). A Study on Traffic and Environmental Effects of Cooperative Delivery System in CBD – Case of Marunouchi District, **World Conference on Transport Research**, Istanbul, Turkey.