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EVALUATING CITY LOGISTICS MEASURES CONSIDERING THE BEHAVIOR OF SEVERAL STAKEHOLDERS

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Abstract: In this paper, we examined a methodology for evaluating city logistics measures while considering the behavior of several stakeholders associated with urban freight transport. We considered five stakeholders of administrators, residents, shippers, freight carriers and urban expressway operators. We assumed that they behaved on the basis of their own criteria for evaluating the effects of city logistics measures, and organized the interaction among these stakeholders. We performed simulation on test road network and implemented truck ban and tolling of urban expressway as city logistics measures. Results indicated that implementation of these measures did not improve the conditions of all stakeholders exactly but it was favorable for them approximately. Also, we could point out that truck ban had an effect to disperse the zones that residents make a complaint and provide an equal environment for residents.

Key Words: City logistics, Stakeholders

1. INTRODUCTION

The concentration of traffic has generated negative impacts on living environment in urban areas. It is important to examine several city logistics measures as trucks impose large negative impacts on the environment than the cars.

Many studies about city logistics measures have been undertaken in the past. Taniguchi *et al.* (2000) presented the methodology for evaluating city logistics initiatives using dynamic traffic simulation. Visser *et al*. (1999) presented a general overview of public policy and planning in the field of urban freight transport. Yamada *et al*. (2001) developed a co-operative vehicle routing and scheduling model with optimal location of logistics terminals.

There are several stakeholders associated with the urban freight transport problems, so it is necessary to consider the behavior of these stakeholders in examining and evaluating city logistics measures. However, there have been few studies that considered the behavior of these stakeholders.

In this paper, we examine a methodology for evaluating city logistics measures while considering the behavior of several stakeholders associated with urban freight transport. As it is important to use existing road network capacity including urban expressways effectively, we examine tolling of urban expressways as a kind of city logistics measures.

2. MODELING BEHAVIOR OF STAKEHOLDERS

2.1 Stakeholders

There are several stakeholders associated with urban freight transport. It can be thought that these stakeholders have their own objectives, and thus behave to achieve those objectives. When city logistics measures are implemented and their living environments are changed, the behavior of these stakeholders will change to adapt to the environments. Therefore, we have to describe the behavior of these stakeholders in evaluating city logistics measures. In this paper, we considered five stakeholders as follows:

- Freight carriers
- Shippers
- Residents
- Administrator
- Urban expressway operators

2.2 Criteria for stakeholders for evaluating city logistic measures

Stakeholders would need to evaluate the environment they are placed when they behave to achieve their own objectives. Therefore, it is necessary to consider the criteria to evaluate. In this paper, we tried to define the objectives of stakeholders first and try to consider their own criteria.

(a) Freight carriers
We assumed that the objective of freight carriers was "Growth in profit". To achieve this objective, freight carriers have to reduce the transportation cost as well as increase the amount of sales. However, in order to reduce the complexity of the analysis, in this paper, we assumed that the amount of sales was fixed and considered the reduction of the transportation cost only.

Objective: **Growth in profit**
↓
Conditions for achieving objective: **Reduction of the transportation cost**, Growth in sales
↓
Criterion: **Transportation cost,** Amount of sales
(Minimize) (Maximize)

Figure 1. Determination Flow of the Criterion for the Freight Carriers

(b) Shippers
The objective of the shippers could also be mentioned as "Growth in profit". To achieve this objective, the shippers have to reduce the total cost as well as increase the amount of sales. However, as before, we assumed that the amount of sales was fixed and considered only the reduction of total cost. The total cost would consist of the opportunity cost, manufacturing (or purchasing) cost and logistics cost, but we assumed that manufacturing (or purchasing) cost was fixed. Logistics cost would consist of inventory cost, transportation cost (cost for outsourcing to freight carriers) and information processing cost, but we assumed that these costs were fixed. Therefore, we considered only the opportunity cost. As we could not

measure the opportunity cost accurately, the criterion for the freight carriers was determined to length of delay time at customers as an alternative.

Objective: **Growth in profit**
↓
Conditions for achieving objective: **Reduction of the total cost,** Growth in sales
↓
Criterion: **Total cost (minimize**), Amount of sales (maximize)
↓
Manufacturing (or purchasing) cost, **Opportunity cost,** Logistics cost
↓
Punctuality of transportation
↓
Length of delay time at customers

Figure 2. Determination Flow of the Criterion for the Shippers

(c) Residents
The objective of the residents could be considered as "ensuring good living environment". To achieve this objective, it is necessary to reduce the negative impact on the living environment from the traffic. Therefore, we used the NOx emissions from the trucks as the criterion for the residents.

Objective: **Ensuring good living environment**
↓
Conditions for achieving objective: **Reduction of negative impacts on living environment from the traffic**
↓
Criterion: **NOx emissions from the trucks**

Figure 3. Determination Flow of the Criterion for the Residents

(d) Administrators
The objective of the administrators could be considered as "revitalization of the city". This objective has economical and environmental aspects, and we have to consider both. However, in considering the city logistics measures, we can address the economical aspect by the transportation cost to some extent. Therefore, we considered only the environmental aspect. It could be argued that good living environment can be attained when the environmental standards are achieved. However, it is difficult to compare the environmental standards in the test case studies discussed in this paper. Therefore, we assumed the total NOx emissions in the network and the total number of complaints from the residents as the criteria for the administrators.

Objective: **Revitalization of the city**
a) Society with low environmental impact
b) Society with high economic efficiency
↓
Conditions for achieving objective: **a) Achieving environmental standards**
b) Efficient use of urban road network
↓
Criterion: **a) Total NOx emissions in the network**
Total number of complaints from the residents

Figure 4. Determination Flow of the Criterion for the Administrators

(e) Urban expressway operators

It could be considered that the urban expressway operators have two objectives of "maintaining profitability" and "providing good traffic environment", but in this paper, we considered only the first objective. To achieve the objective of "maintaining profitability", the urban expressway operators have to increase the toll revenue and reduce the construction/maintenance costs. We assumed that the construction/maintenance costs were fixed and considered only the toll revenue. Therefore, the criterion for the urban expressway operators could be determined by the toll revenue.

Objective: **Maintaining profitability,** Providing good traffic environment
↓
Conditions for achieving objective: **Increase in toll revenue**, Reduction of construction/maintenance costs
↓
Criterion: **Toll revenue**

Figure 5. Determination Flow of the Criterion for the Urban Expressway Operators

2.3 Modeling the behavior of stakeholders

Stakeholders could be assumed to maximize the level of their criteria. In this section, we try to describe the behavior of each stakeholder.

(a) Freight carriers

The behavior of freight carriers could be considered as planning and implementing the delivery schedule of the trucks so as to minimize the "transportation cost". To model such behavior, we adopted the model for vehicle routing and scheduling problem with time window (VRP-TW-F) (Taniguchi *et al.* (2001)). We explain about this model in detail in the next section.

(b) Shippers

Shippers want the goods to be delivered on time. Therefore, we assumed that the shippers would implement delay penalty to force the freight carriers to be punctual. In this paper, they are considered to make a complaint and charge a delay penalty on freight carriers each time the goods are delivered late. In addition, we assumed that they put a pressure on the freight carriers by increasing the delay penalty for the subsequent delivery.

(c) Residents
Residents would demand the NOx emissions from the trucks to be reduced. It is assumed that they would exert a pressure on the administrators to achieve that objective. Therefore, we assumed that the residents would make a complaint against administrator when the level of NOx emissions exceeds the predefined limit.

(d) Administrators
The criterion for the administrators was assumed to be the reduction of the total NOx emissions in the network and also minimize the total number of complaints from the residents. In this paper, it was assumed that the behavior of the administrators was assumed to implement the city logistics measures when the residents complain.

(e) Urban expressway operators
Urban expressway operators would want to increase the toll revenue. Thus, in this paper, they were assumed to implement toll measures.

Reflecting these behaviors, interaction among stakeholders could be described as follows. If the freight carriers deliver late for the time windows, the shippers charge delay penalty and increase the delay penalty for the subsequent delivery. Also, Trucks of the freight carriers evacuate NOx and affect the living environment of the residents. When NOx emissions from the trucks exceed the predefined limit, the residents make a complaint against the administrators, and the administrators implement the city logistics measures. City logistics measures affect the freight carriers. Also, when the urban expressway operators implement the toll measures, the freight carriers are affected. Then, freight carriers have to revise the delivery schedule, and the condition of the road network is changed.

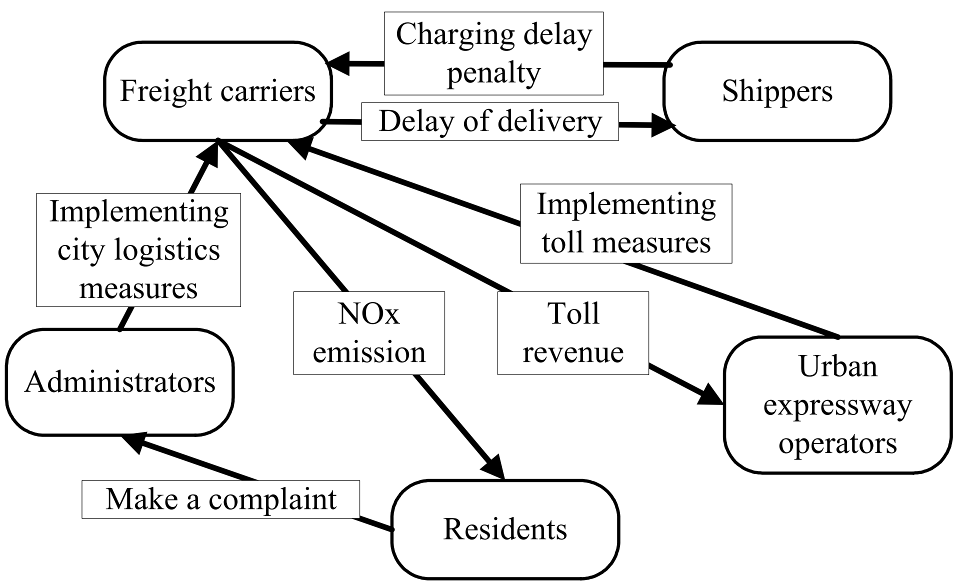

Figure 6. Interaction among Stakeholders

3. VRP-TW-F MODEL

VRP-TW-F Model determines the optimal solution by minimizing total transportation costs. Total transportation costs are composed of three components; (a) the fixed cost of vehicles,

(b) vehicle operating costs that are proportional to the time traveled, and (c) early arrival and delay penalty for designated pickup/delivery time at customers. The model can be formulated as follows:

Minimize

$$C(\boldsymbol{t_0}, \mathbf{X}) = \sum_{l=1}^{m} c_{f,l} \cdot \delta_l (\mathbf{x}_l) + \sum_{l=1}^{m} C_{t,l}(t_{l,0}, \mathbf{X}_l) + \sum_{l=1}^{m} C_{p,l}(t_{l,0}, \mathbf{X}_l) \quad (1)$$

where

$C(\boldsymbol{t_0}, \mathbf{X})$: total cost (yen)

$\boldsymbol{t_0}$: departure time vector for all vehicles at the depot

$\boldsymbol{t_0} = \{ t_{l,0} \mid l = 1, \cdots, m \}$

$\mathbf{X}$: assignment and order of visiting customers for all vehicles

$\boldsymbol{X} = \{ \boldsymbol{X}_l \mid l = 1, m \}$

$\boldsymbol{X}_l$: assignment and order of visiting customers for vehicle *l*

$\boldsymbol{X}_l = \{ n(i), \mid i = 1, N_l \}$

$n(i)$: node number of *i* th customer visited by vehicle *l*

$d(j)$: number of depot (=0)

N_l : total number of customers visited by vehicle *l*

m : maximum number of vehicles available

$c_{f,l}$: fixed cost for vehicle *l* (yen)

$\delta_l(\mathbf{x}_l)$: =1; if vehicle *l* is used, =0; otherwise

$C_{t,l}(t_{l,0}, \mathbf{X}_l)$: operating cost for vehicle *l* (yen)

$C_{p,l}(t_{l,0}, \mathbf{X}_l)$: penalty cost for vehicle *l* (yen)

The problem described here is a NP-hard (Non-deterministic Polynomial-hard) combinatorial optimization problem. Therefore, it requires heuristic algorithms. The model described here uses a Genetic Algorithms (GA) to solve the VRP-TW-F.

4. CASE STUDIES

4.1 Test conditions

Figure 7 shows the test road network that was used for the case studies. This network is assumed to be in an urban area and consists of 69 nodes and 298 links including 58 links of urban expressway. There are 10 freight carriers in the network and they have their own depots and customers (20-24 customers for each freight carriers). Each freight carrier has 12 trucks (four 2 ton trucks, four 4 ton trucks, and four 10 ton trucks) and can use these trucks flexibly. Depot and customers are located randomly on this network. Each customer has his own goods and the time window for arrival. Goods volume and range of time window for each customer were determined based on the goods movement survey in the Keihanshin area conducted in 1994.

We assumed that the shippers would increase the delay penalty by 10 yen per minute for the subsequent delivery whenever goods are delivered late. There is one urban expressway

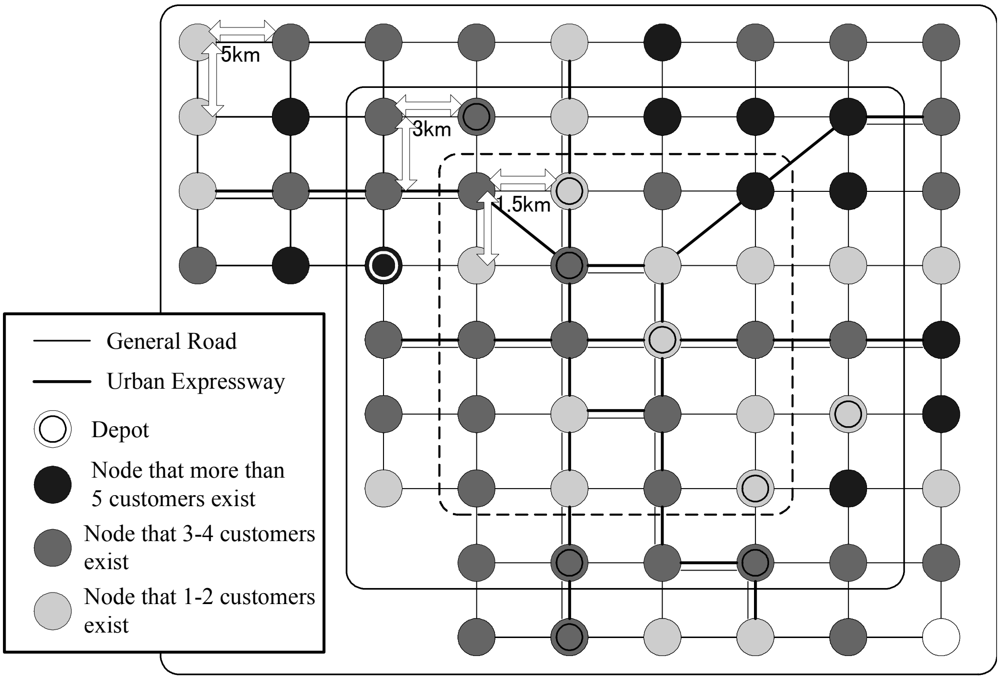

Figure 7. Test Road Network

operator in the network. The toll for the urban expressway was assumed to change proportional to the travel distance. We set the toll for medium and small trucks (including 2 ton and 4 ton trucks) to be 50 yen per kilometer, and 100 yen per kilometer for large trucks (including 10 ton trucks). We defined the area between two nodes that were connected by one link as a zone unit. There are residents in all zones in the network, and we assumed that the residents would make a complaint against the administrators whenever the NOx emissions for their zone exceed 50g per 1km.

We considered truck ban as the city logistics measures that can be undertaken by the administrators. Specifically, it was assumed that when the residents in a zone made a complaint, the administrators implemented the truck ban to all the links included in that zone except for urban expressway links. Also, as measures by the urban expressway operators, we considered reducing the expressway toll to half-price. List of the case studies in this paper is as follows.

Case1: Toll for urban expressway is normal. Truck ban is not implemented (base case)
Case2: Toll for urban expressway is normal. Truck ban is implemented
Case3: Toll for urban expressway is half-price. Truck ban is not implemented
Case4: Toll for urban expressway is half-price. Truck ban is implemented

Flow of calculation is shown in Figure 8. At first, each of ten freight carriers plans and implements the delivery schedule of trucks by using VRP-TW-F Model, and goods are delivered. Based on the travel of the trucks, NOx emissions for each zone and delay times at each customer are calculated. Then, if there are some zones that NOx emissions exceed the limit (50g per 1km), the residents in those zones make a complaint against the administrators. In Case2 and Case4, the administrators implement the truck ban to all the links included in those zones except for the urban expressway links. However, in Case1 and Case3, the administrators ignore the complaints and do not implement the truck ban. Also, if trucks arrive late for the time windows of some customers, shippers charge the delay penalty and increase the delay penalty at those customers by 10 yen per minute for the subsequent delivery. Reflecting these results, the condition of the network is updated. We iterated this flow 20 times. Also, we repeated this iteration 5 times by changing random seed in random number generator in VRP-TW-F model and averaged the results of calculations.

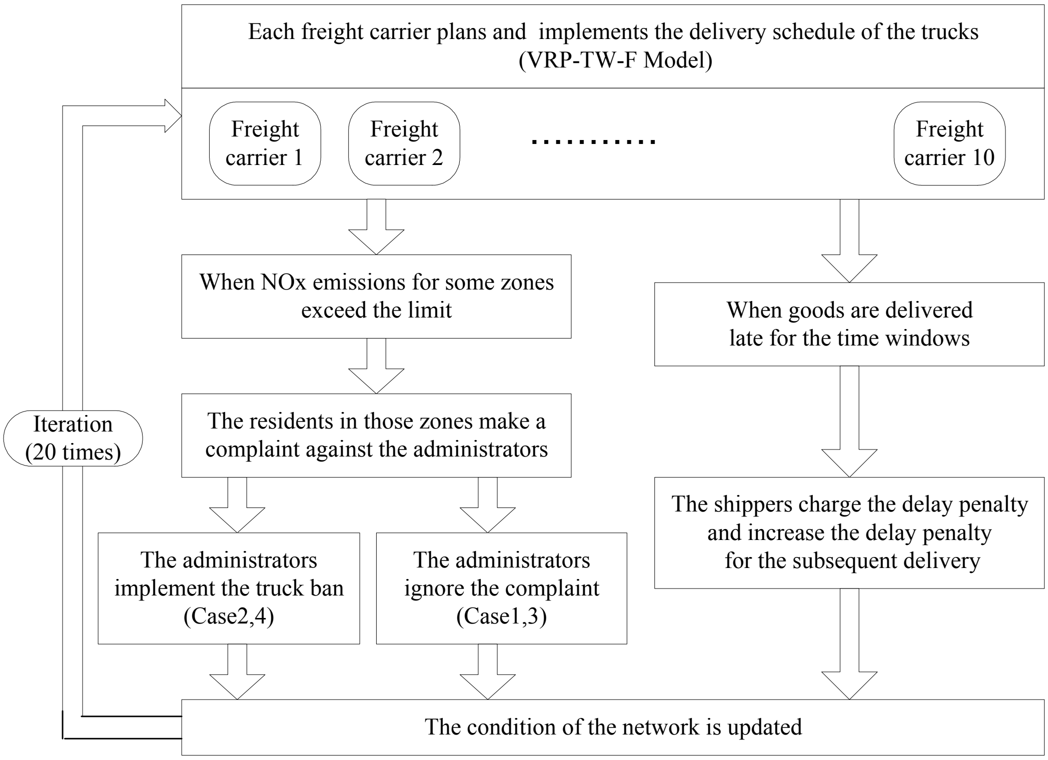

Figure 8. Flow of Calculation

4.2 Test results

Figure 9 shows the total transportation cost of ten freight carriers. This result is the average of the 20 iterations. It can be seen that there is no difference among four cases. Therefore, these measures do not have influence on freight carriers. Table 1 shows the breakdown of the transportation cost. From here, we can understand that the operating cost is reduced and the cost for the urban expressway increases when the toll is reduced to half-price. Therefore, it can be mentioned that the freight carriers shorten the running time of the trucks by using urban expressway more frequently when the urban expressway becomes useful. This result is favorable for the urban expressway operators because the toll revenue increases. However, we have to calculate by changing the network condition (network size, location of customers, number of customers etc.) because the rate of increase of the cost for the urban expressway seems too large.

The total delay time at the customers is shown in Figure 10. We can understand that the total delay time increases by implementing the truck ban when the urban expressway toll is normal. As it can be seen the ratio of delay penalty in the total transportation cost is small, we

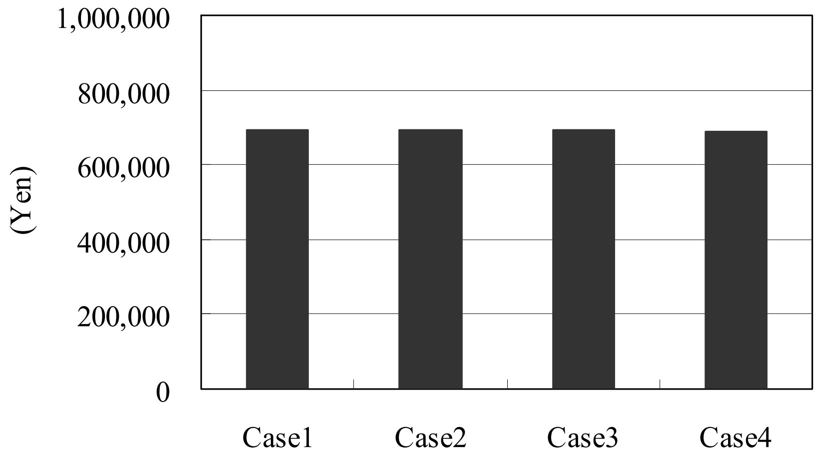

Figure 9. Total Transportation Cost

Table 1. Total Transportation Cost

	Case1	Case2		Case3		Case4	
Operating cost	205,904	206,862	*100%*	185,737	*90%*	186,216	*90%*
Delay penalty	1,495	2,415	*162%*	1,877	*126%*	1,887	*126%*
Early arrival penalty	62,379	62,063	*99%*	65,040	*104%*	67,866	*109%*
Fixed cost	421,215	417,718	*99%*	427,302	*101%*	420,148	*100%*
Cost for the urban expressway	1,624	2,986	*184%*	13,457	*828%*	14,731	*907%*
Total cost	692,618	692,044	*100%*	693,413	*100%*	690,848	*100%*

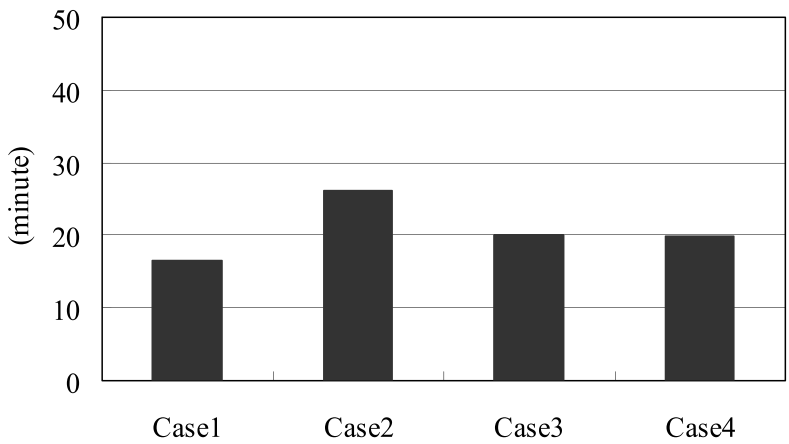

Figure 10. Total Delay Time at the Customers

can understand that the freight carriers tend to avoid the increase of burden caused by the truck ban by increasing delay time. However, this increase of delay time is released when the urban expressway toll is reduced to half-price.

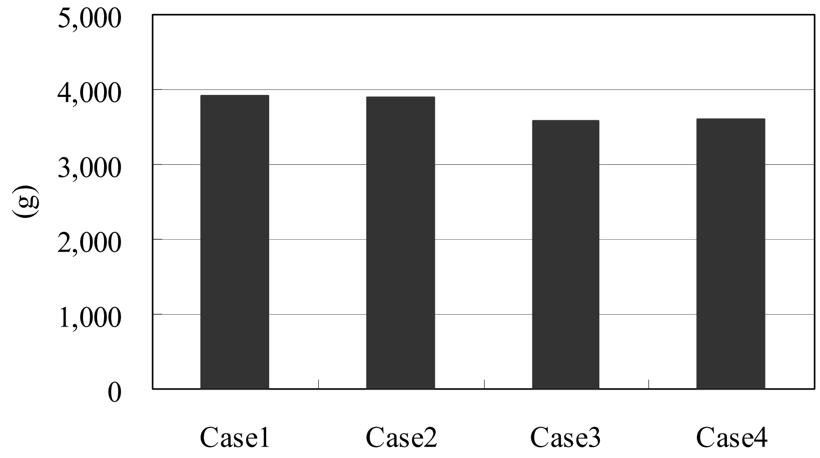

Figure 11. Total NOx Emissions from the Trucks

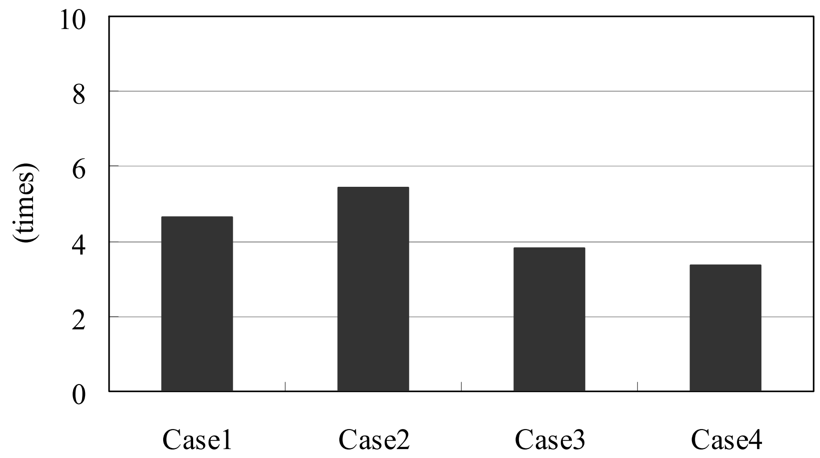

Figure 12. Total Number of the Complaints from the Residents

Figure 11 shows the total NOx emissions from the trucks. There is no difference in Case1 and 2. However, the NOx emissions are reduced when the expressway toll is reduced to half-price.

Figure 12 shows the total number of complaints from the residents. In Case2, total number of complaints increases compared with Case1. Figure 13 and 14 shows the incidence of the complaints from the residents at each zone in Case1 and Case2. Comparing these two figures, we can understand that the zones that complaints occurred spread and the incidence at each zone becomes lower wholly when the truck ban is implemented. Therefore it can be mentioned that the truck ban has the effect to disperse the zones that the residents make a complaint and provide an equal environment for the residents in the network.

When the expressway toll is reduced to half-price, the total number of complaints decreases. Therefore, it can be mentioned that promotion of using the urban expressway contributes to reduce the NOx emissions and the complaints from the residents are reduced in consequence.

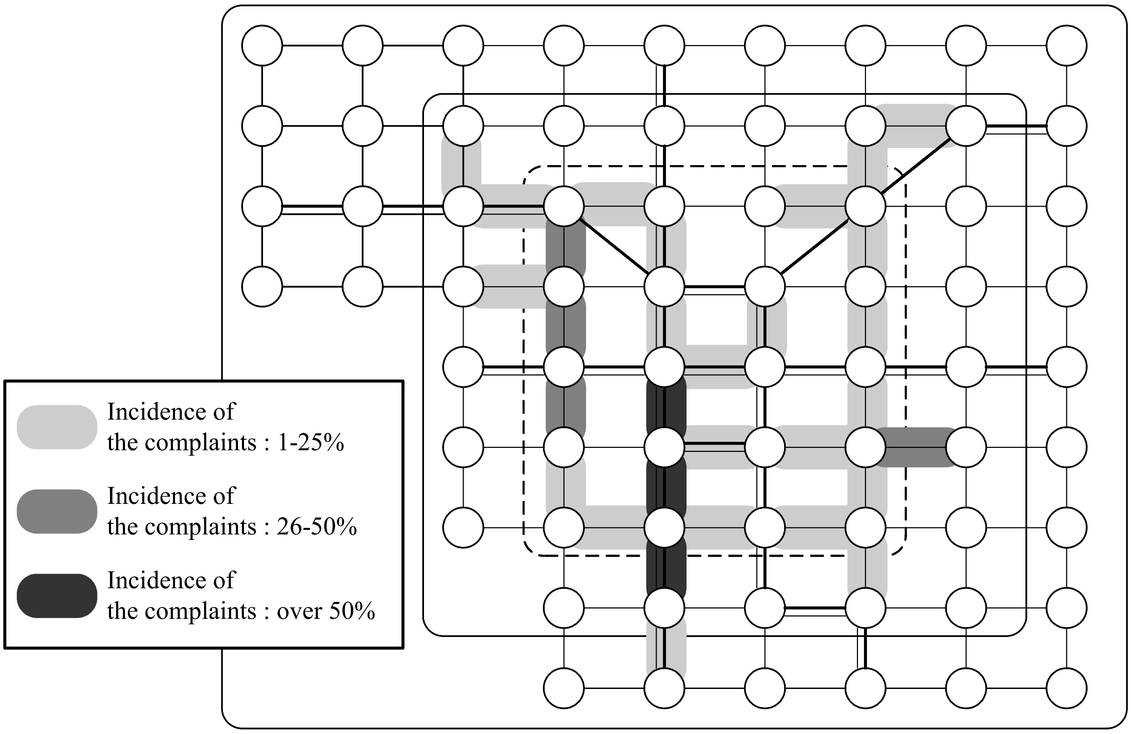

Figure 13. Incidence of the Complaints from the Residents (Case1)

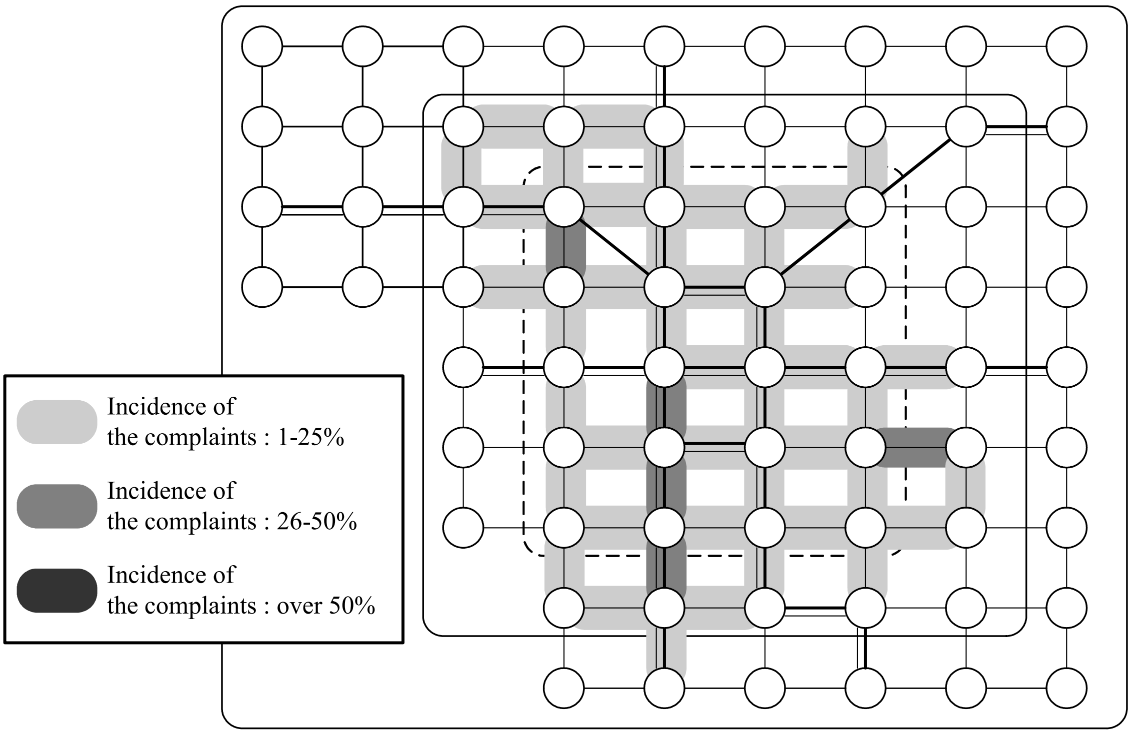

Figure 14. Incidence of the Complaints from the Residents (Case2)

Figure 15 and Figure 16 shows the incidence of the complaints from the residents in Case3 and Case4. It can be seen the same trend with Case1 and Case2.

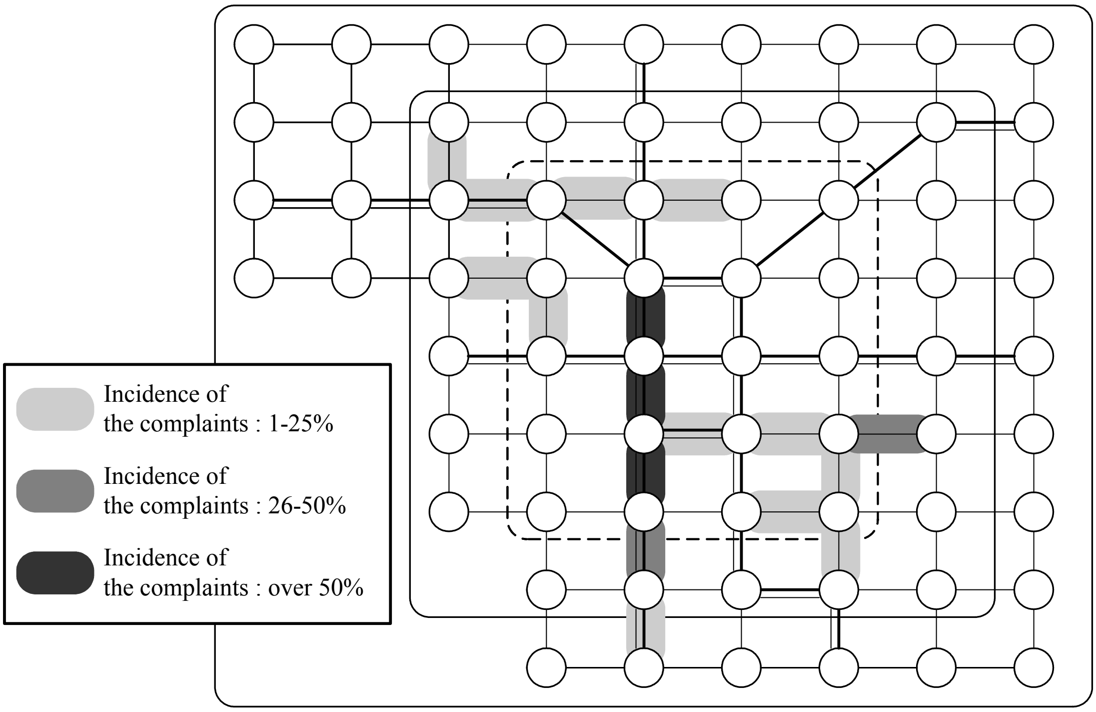

Figure 15. Incidence of the Complaints from the Residents (Case3)

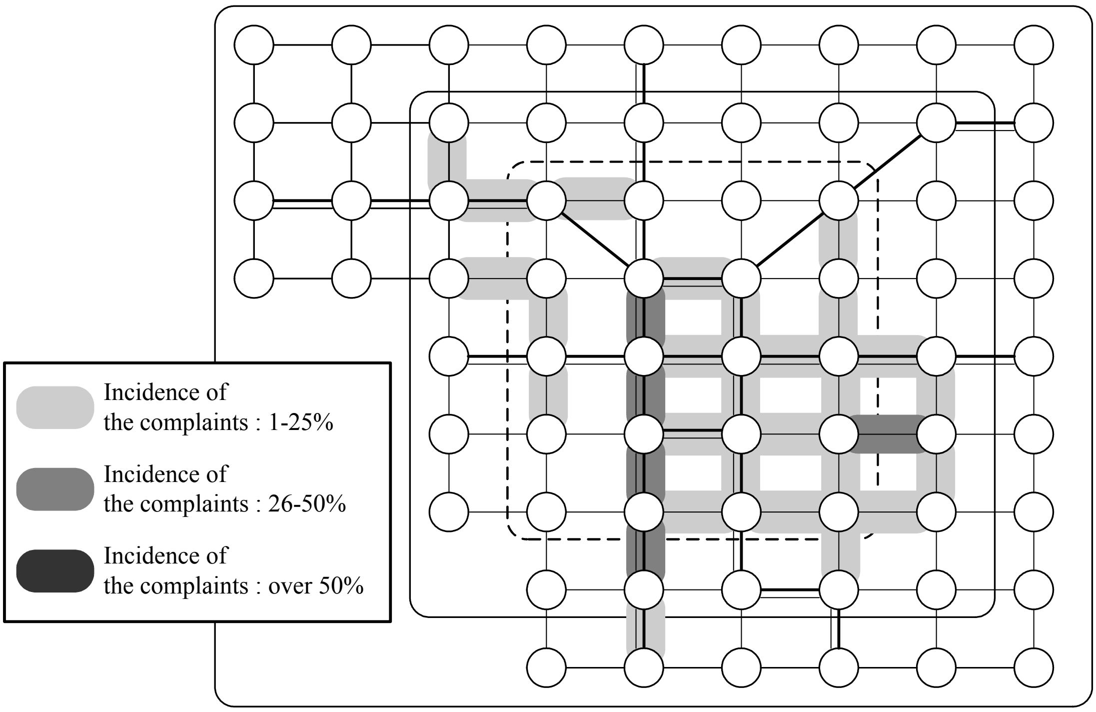

Figure 16. Incidence of the Complaints from the Residents (Case4)

Figure 17-19 show the performance of each case. We assumed that Case1 was base case and considered performance for each criterion. As for the transportation cost, delay time, NOx emissions and complaints, we assumed the inverse of proportion of each case to Case1 as a performance of each case. On the other hand, performance of the toll revenue was assumed to be the proportion to Case1.

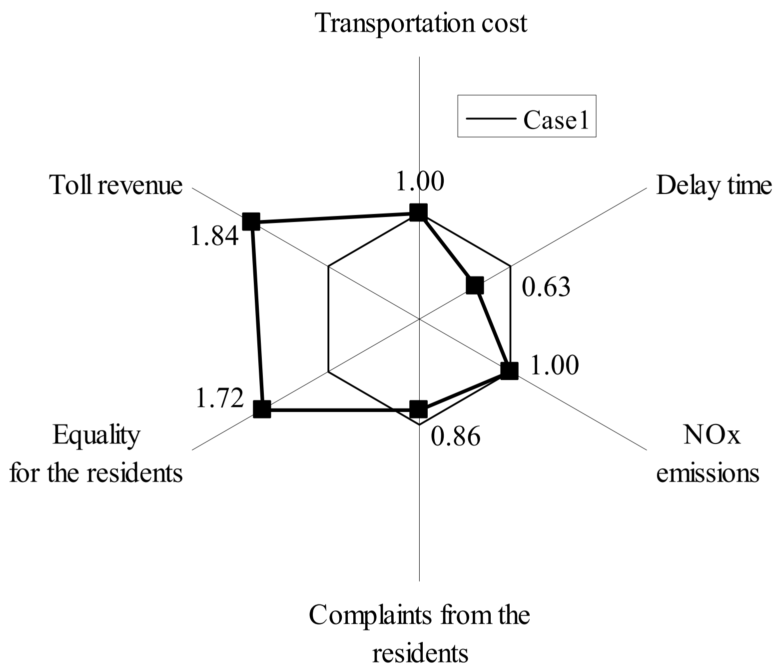

Figure 17. Performance of Case2

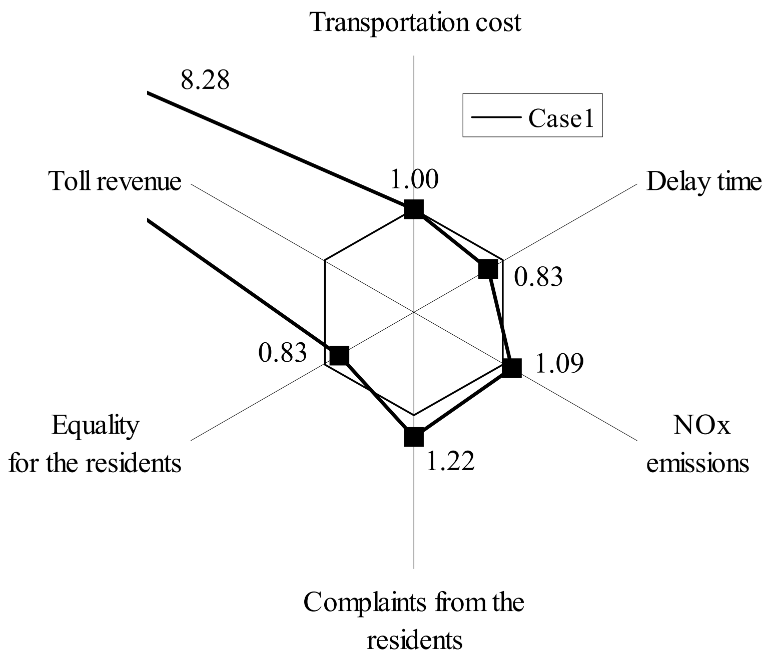

Figure 18. Performance of Case3

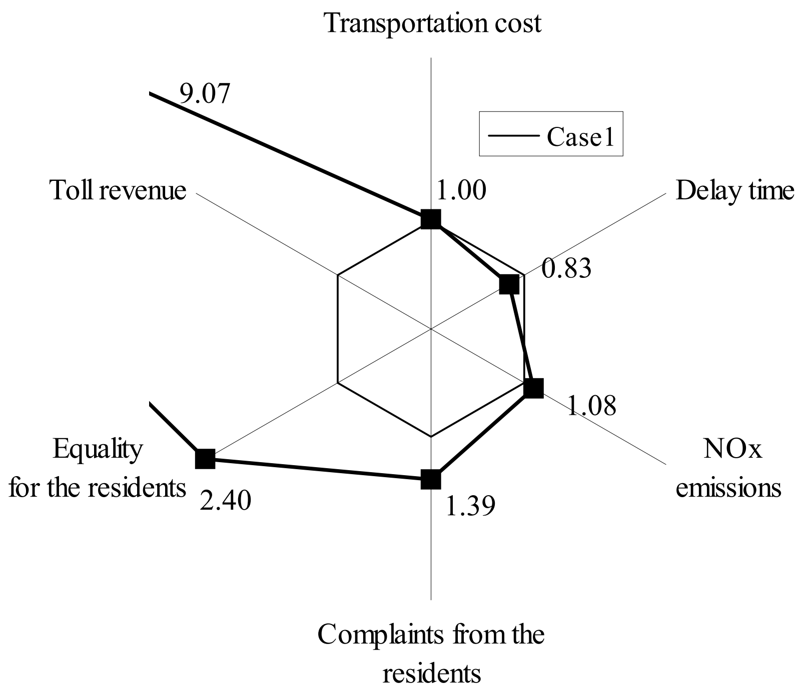

Figure 19. Performance of Case4

Table 2. Performance of each criterion

Transportation cost	Inverse of proportion to Case1
Delay time	
NOx emissions	
Complaints from the residents	
Toll revenue	Proportion to Case1
Equality for the residents	Inverse of proportion of variance of complaints frequency at each zone to that of Case1

As mentioned above, the truck ban has an effect to provide an equal environment for the residents. It is important to make all of the residents live in equal environment. Therefore, we added “Equality for residents” as the criterion. We calculated variance of complaints frequency at each zone, and considered inverse of proportion of that of each case to that of Case1 as a performance of each case for “Equality for residents”. Therefore, value of performances described here grows larger when the result of evaluation becomes better.

Both in Case2 and Case3, performances are better approximately compared with Case1 except for delay time. Case4 is evaluated highly in particular. However there is no case that all performances get better. This result indicates difficulty of implementing city logistics measures that is favorable for all stakeholders associated with urban freight transport. However, it can be seemed that there are many city logistics measures other than those implemented in this study. Therefore, we have to implement (and combine in some cases) and evaluate city logistics measures continuously.

5. CONCLUSIONS

This paper examines a methodology for evaluating city logistics measures in considering the behavior of several stakeholders associated with urban freight transport. We considered the criterion for each stakeholder and described the behavior of each stakeholder. After that, we made a simulation in test road network and implemented truck ban and tolling of urban expressway as city logistics measures. The result indicates that both of measures do not influence total transportation cost. However, reducing the toll to half-price is favorable for the residents and the administrators. In addition, we can point out that the truck ban has the effect to disperse the zones that the residents make complaints and provide an equal environment for the residents.

For further studies, we need to make a simulation in various network conditions and accumulate the knowledge. In addition, we need to evaluate various kinds of city logistics measures and examine effective and favorable implementation of city logistics measures for all stakeholders associated with urban freight transport.

REFERENCES

Taniguchi, E. and R.E.C.M. van der Heijden (2000) An evaluation methodology for city logistics. **Transportation Reviews, 20(1)**, 65-90

Taniguchi, E., Thompson, R.G., Yamada, T. and van Duin R. (2001) **City Logistics --- Network Modelling and Intelligent Transport Systems**. Pergamon, Oxford.

Visser, J., Binsbergen, A.J. van and Nemoto, T. (1999) Urban freight transport policy and planning. In E Taniguchi and R.G. Thompson (eds.) **City Logistics Ⅰ**, Institute of System Science Research, Kyoto, 39-69

Yamada, T., Taniguchi, E. and Itoh, Y. (2001) Co-operative vehicle routing model with optimal location of logistics terminals. In E Taniguchi and R.G. Thompson (eds.) **City Logistics Ⅱ**, Institute of System Science Research, Kyoto, 139-153