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Urban Goods Transport of Medan: Basic Survey and Scenario Analysis

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Abstract. This paper intends to propose a simple and effective methodology to collect urban goods transport data in developing cities and to analyze the urban policies based on the freight traffic flow model. As a case study, we surveyed the goods transport in Medan, Indonesia. We interviewed the related people, counted the traffic flows at major road accessing the CBD, and interviewed enterprises to collect the goods transport data. We estimated the freight traffic flow simulation model by synthesizing the collected data. Then, two land-use scenarios of the area where the airport is now located are discussed under the condition that the airport will be relocated. By applying the model, we found that the traffic volume and air pollution will increase when no countermeasure is taken in the commercial development scenario.

1. INTRODUCTION

Medan is the third largest city located at North Sumatra, Indonesia. Medan does not have so serious problems right now in terms of transportation, because it has not yet developed much from the viewpoints of city's physical scale and population. However, the Medan city may face the rapid increase of traffic demand and suffer from serious shortage of transportation infrastructure in the near future, because the rapid increase of population and the growth of economy of Medan will be expected like other Asian cities. When looking at the national transportation policy of Indonesia, Medan does not seem to be considered as the city with the highest priority for investing the transportation facilities by the central government. This may be because Indonesia has serious financial difficulties due to many domestic problems such as the Eastern Timor issue, the Ache dispute and the Big Earthquake off the Sumatra Island in 2004. Therefore, the transportation policy of Medan has never yet been neither researched nor discussed very well even in Indonesia. In addition, Medan, like other many developing cities, has a problem that the basic statistics are not well developed for a discussion of the urban transportation policy. In general, as far as the mega-cities like Jakarta is concerned, the large-scale surveys have been conducted by several international institutes including JICA and WB, but the middle-size and small-size cities do not have the transportation data such as the person trip data and the freight transport data. Due to the lack of basic data, the analysis for urban transportation policy is very difficult.

By the way, there are many cities in Asia which has the same size of population as Medan and which has the same position in the country as Medan. And it can be expected that these cities have the similar urban problems to Medan. Moreover, generally speaking, as there are very few local research institutes like universities in the middle-class cities, they run short of the persons and the knowledge for analyzing the urban problems. It may be very meaningful to propose the practical methodologies of

survey and analysis for middle-size developing cities.

Therefore, first, we will examine and conduct a simple survey method to collect the data of urban goods transport with lower time and cost than the usual survey. Then, we develop an empirical model dealing with the urban freight traffic flow based on the collected data, by which we can simulate the freight vehicle flow under the given transport policy. Finally we discuss the two scenarios in a case of the relocation of the airport in Medan by using the developed simulation model.

2. OUTLINE OF MEDAN CITY

2.1 Socioeconomic background of Medan city

Medan is located at the northern part of Sumatra, Indonesia, at latitude 3 degree north (see Figure 1). It is the regional capital of Deri Surtan prefecture, North Sumatra with the largest population in Sumatra. Its area is about 260 km^2 (about 30 km from north to south and about 10 km from east to west) including 21 local wards (*kecamatan*) and 144 towns (kelurahan). The population of Medan city is about two million as of the year of 2003 and it keeps growing with the increasing rate of population of 6.0 % in 2003. In terms of religion, Medan is the Muslim-oriented city with 67.2 % of population of Muslim, 18.3 % of Protestant, 5.4 % of Catholic and 7.2% of Buddhism.

Figure 1: Medan city: located at the northern part of Sumatra Island

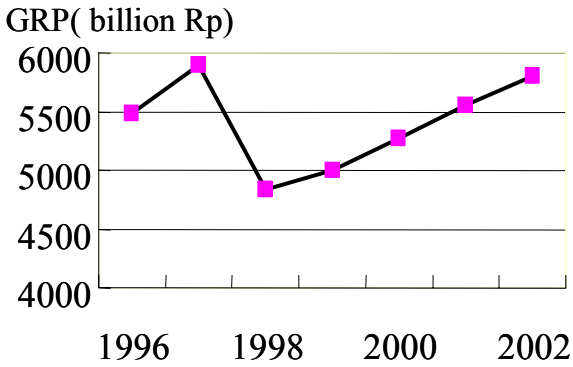

Figure 2: Recent trend of GRP of Medan (prices as of FY 1993)

The gross regional product of Medan city is shown in Figure 2. This figure indicates that Medan has been developing in terms of macroscopic economic viewpoint except in 1997 when the Asian Crisis occurred. About 36% of total product of Medan generates from trading and restaurant whereas about 20% generates from the manufacture. The industrial area of light industry is located at the northern part of Medan, which mainly exports the products to other countries from Belawan port.

2.2 Transportation Infrastructure of Medan city

The road network in Medan city consists of local highway with the low standard of structure. As the road network with the high standard, only one expressway is running at the eastern part of Medan city. The road network is shown in the map of Figure 3. The construction of ring road has been proposed in the Urban Infrastructure Plan of Medan. This aims to have a role as a bypass route for the traffic between the southern part of Medan city and the port area located at the northern part of the city. Now, the inner ring road (JJLD) and the outer ring road (JJLL) are under construction. At the same time, the road capacity is increased by the construction of urban road network. In addition to the new investment of road network, the investment of public transport terminal for inter-city transport has started based on the strategy shown in the Urban Infrastructure Plan of Medan. On the railway network, there exists the long rail infrastructure, but it is not maintained well although it becomes very older. Though the rail service for long distance passenger is provided, it is very limited. The agricultural products are mainly transported by this railway. The railway network passing through Medan city connects several small cities of North Sumatra. The data of 1986-1990 shows that both freight and passenger transport by rail has decreased by 20.5 % annually in freight rail transport and decreased by 6.85% annually in passenger rail transport. In terms of air transport, the Polonia airport is located at about 2 km northern part of CBD of Medan city. The relocation of the airport is now discussed due to rapid

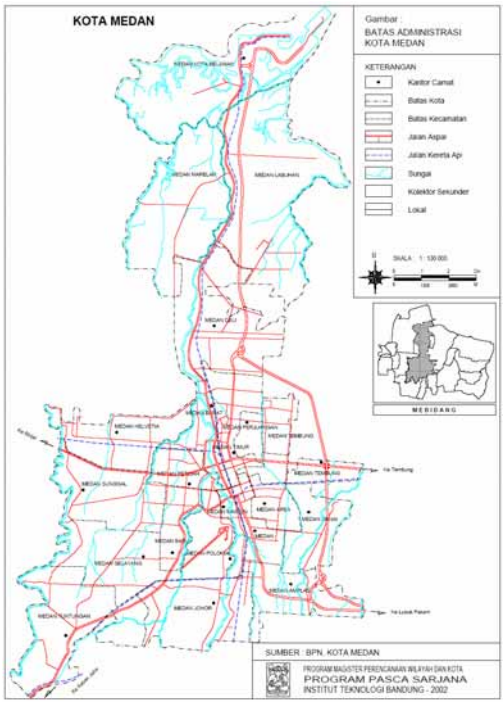

Figure 3: Road network of Medan city

increase of air transport demand and the lack of airport capacity. The place of relocation of the airport is researched by the central government, but the exact place has not yet been decided as of the end of 2004.

3. SURVEY ON GOODS TRANSPORT IN MEDAN CITY

3.1 Outline of the survey

We survey the goods transport of Medan city to collect the basic data. The survey consists of three steps:

1) Preliminary survey: a rough survey on the urban structure and the infrastructure by visiting the sites of the city

2) Preparatory survey: interviews to authorities and related institutions and the survey on the distribution of number of companies by its size in Medan

3) Field survey: a traffic volume survey of major roads of Medan and an interview survey to business companies on goods transport.

First, we stayed Medan city for four days in March, 2004, that is, eight month before the field survey, in order to grasp the general situation by visiting sites of transportation facilities in city, including the Polonia airport, the central railway station and main roads.

Next, one of us stayed Medan city for 17 days in November and December, 2004 to conduct the preparatory survey and the field survey. The local non-governmental organization, the Badan Warisan Sumatra Heritage Trust (BWS), which mainly works for the conservation of historical heritage, supported our preparatory survey and field survey. The reasons why we conducted the preparatory survey are firstly because to get the general information of social background of Medan is so critical to discuss the

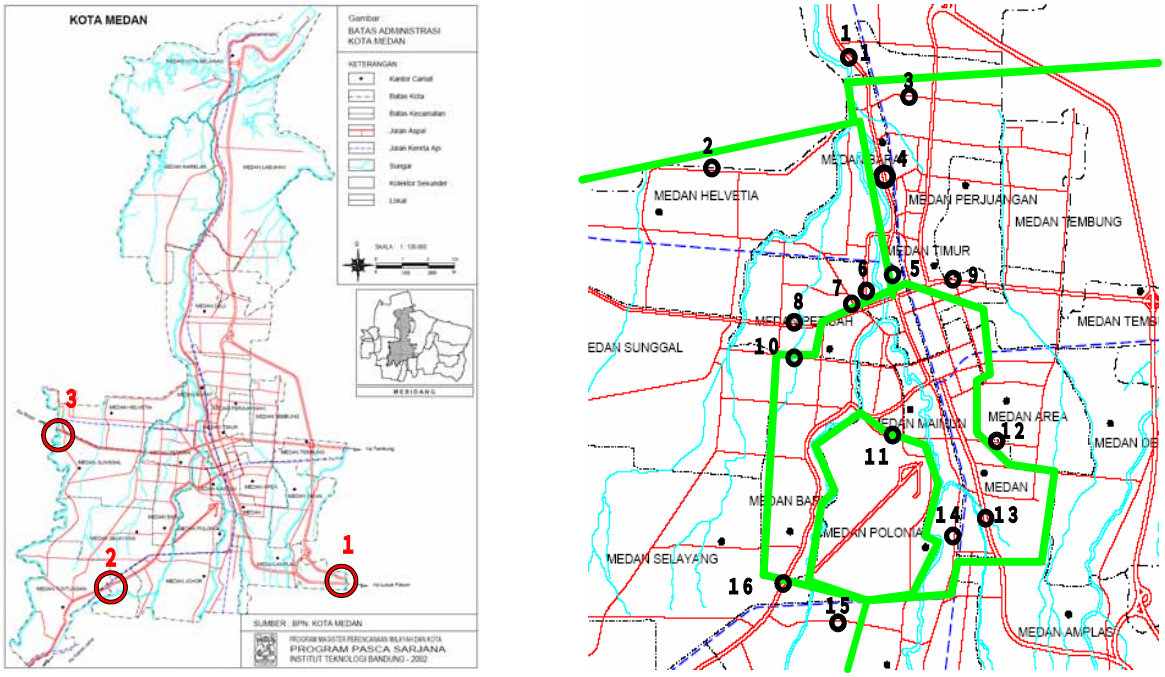

Figure 4: Observation points of traffic volume survey (left: 24-hour survey and right: half-day survey)

direction of future transportation policy, secondly because understanding the local commercial customs is so important to analyze the goods movement and third because to get the geographical information of Medan is essential to select the sites for the field survey.

3.2 Interviews to authorities and related people in the preparatory survey

We interviewed the people shown in Table 1. The most of the interviewees are the authorities of Medan city or the North Sumatra. From these interviews, we found the following things:

- There is no public truck terminal in Medan city
- The warehouse service is not well developed. Most of the local companies use their own warehouses because to get the area for warehouse is quite easy due to low land price and because most of companies have just few connections to trade the goods.
- The wholesale which covers many retailers does not exist. The main reason of no large-scale wholesaler is because of low level of trust of trading, for example, that the punctuality of delivery is very low and the possibility of theft in the process of goods distribution.
- Chinese business people, so-called the "agent" manages the goods distribution by contracting a few number of manufacturers and retailers.
- There is no large-scale company except few petroleum companies in Medan. Most of companies are middle or small companies.

3.3 Survey on the distribution of number of companies by its size

Although we found out that most of the local business is middle or small scale by our preparatory interviews, we could not get the information of the distribution of business by their size because there is no official statistics about the size of enterprises. On the other hand, it may be so important to understand the distribution of the size of business even if it is very rough, because the amount of goods generating the enterprises is closely related to the size of enterprises. As it is impossible to measure the distribution of all companies in Medan city, we selected the sample data by making an original observation. First, we selected thirty observation areas in the urban district. Then ten surveyors, mainly local university students, walked around the observation areas. They counted the number of enterprises by categorizing them into three types in size, small (one to four employees), middle (five to nineteen employees) and large (more than twenty employees). We trained them on the method of observation before the survey in

Table 1: Interviewees in the preparatory survey

Interviewees	Visiting place	title
Ir. Rahmat Dian Sembiring	Institut Teknologi of Medan	Professor
Mulia Raja Harahap	Province	Sumatra
Edu	Department of Transportation of Medan	Authority of transportation
Sembiring	Department of Industri and Trading of Medan	Authority of trading
Ir. Sampurno Pohan	Department Of City Planning	Authority of city planning
Ir. Arief Trinugroho	Bappeda of medan	Authority of labor
Yuni	Research Section for lisence in Mayor Office	Authority of general issues of Medan city
Kiyoshi Ishikawa	JICA	JICA specialist
Marwan	BPS of medan city	Authority of statistics in Medan city

order to standardize their sense of size of companies. As the results of this survey, we found that about 83% of companies are small size and 13 % is middle size in average while the distributions are quite different among different area.

3.4 Traffic volume survey

We conducted the traffic volume survey in order to grasp the traffic volume by types of vehicle, which are running along the main roads of Medan. The survey is based on observation by the surveyors standing besides the roads. The places of observation are divided into two types. One type is for 24-hour traffic survey. We selected three points as this type, where the major roads connecting between outside and inside of Medan city cross the border of the city. The other type of observation points are for half-day traffic survey including sixteen points. We started the half-day survey after we had finished the 24-hour survey. One of the reasons of this process is because we need to grasp the general characteristics of traffic patterns such as the dynamic change of traffic volume in a day and the share of vehicles in order to observe the vehicle as efficiently as possible in the half-day survey. We decide the number of observers per observation point and the number of observation points in the half-day survey based on the experience of 24-hour survey. In addition, the traffic counting survey in the mid-night is quite dangerous from the security viewpoint at some parts of Medan cities.

24-hour traffic volume survey

We selected three major points on the border of Medan cities shown in Figure 4. We classified the vehicle into five types, namely motorcycle, sedan, pickup truck, two-axel middle-size truck and three-axel large-size truck. The surveyors counted the traffic volumes by types of vehicle, by time of the day and by direction.

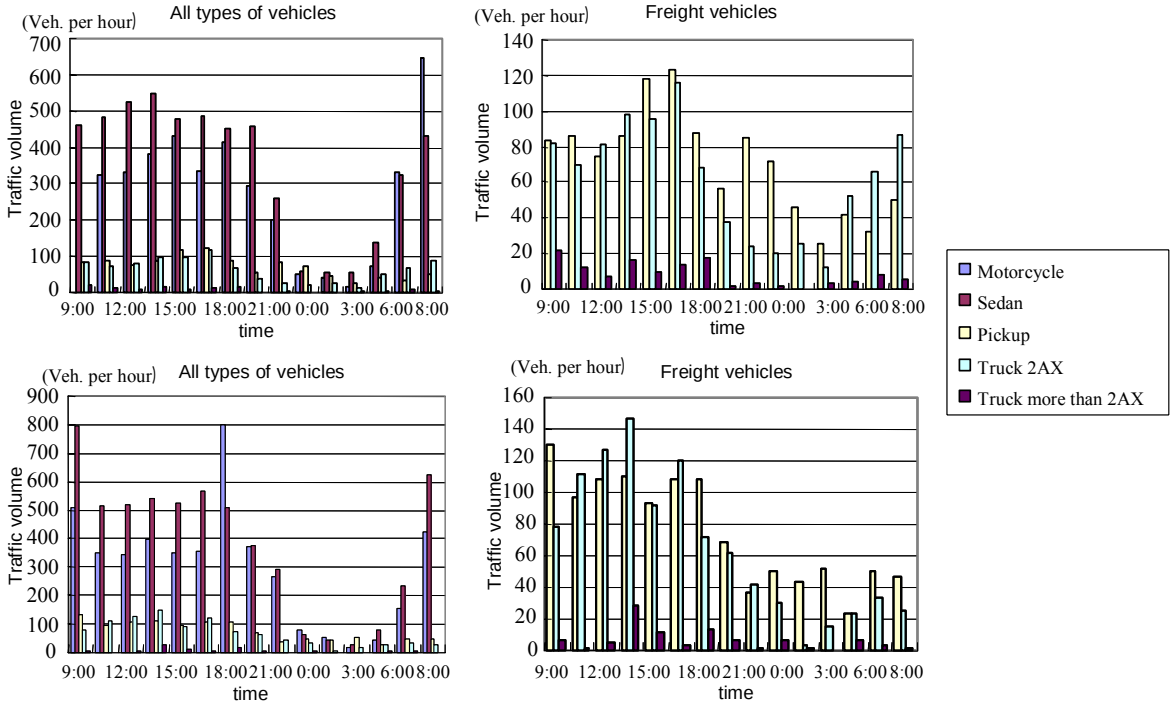

Figure 5: Results of 24-hour traffic volume survey of the Point 2 in Figure 4 left

(upper-left: all vehicles from outside to inside; upper right: freight vehicles from outside to inside; lower-left: all vehicles from outside to inside, lower-right: freight vehicles from inside to outside)

The results of the 24-hour traffic volume survey at the Point 2 in Figure 4 are shown in Figure 5. The lefts of Figure 5 are the dynamic change of the observed traffic volume of a day of all types of vehicles and rights of Figure 5 are the dynamic change of observed traffic volume of a day of freight trucks. The upper of Figure 5 is the observed traffic volume of the direction from the suburban area into the center of city whereas the lower is from the center of city to the suburban area. The results show that

- the modal share of motorcycle is largest and it is about 40% of total traffic volume
- there are two peaks of traffic volumes, one of which is 8:00-9:00 in the morning and the other of which is around 18:00
- there does not seem to be any clear peak of freight traffic volumes. The traffic volume of freight vehicles in the afternoon may be larger than the other time.
- Most of the trucks are pickup trucks or two-axel trucks, that is, just middle-size or small-size trucks are running in the city.

Half-day traffic volume survey

We observed the traffic volume, in the half-day traffic survey, at sixteen points of the major road accessing the central business district of Medan city from 9:00 to 22:00. The sixteen observation points are depicted in the right of Figure 4. In addition to the five types of vehicles observed in the 24-hour survey, we observed the para-transit, so-called the "sudako" as well. As an example of the results, the observed traffic volumes running from west to east at the Point 2 and the Point 8 in the right of Figure 4 are shown in Figure 6. These two roads are the alternative routes for truck drivers from western part and southwestern part of city to eastern and northeastern part of city. The results show

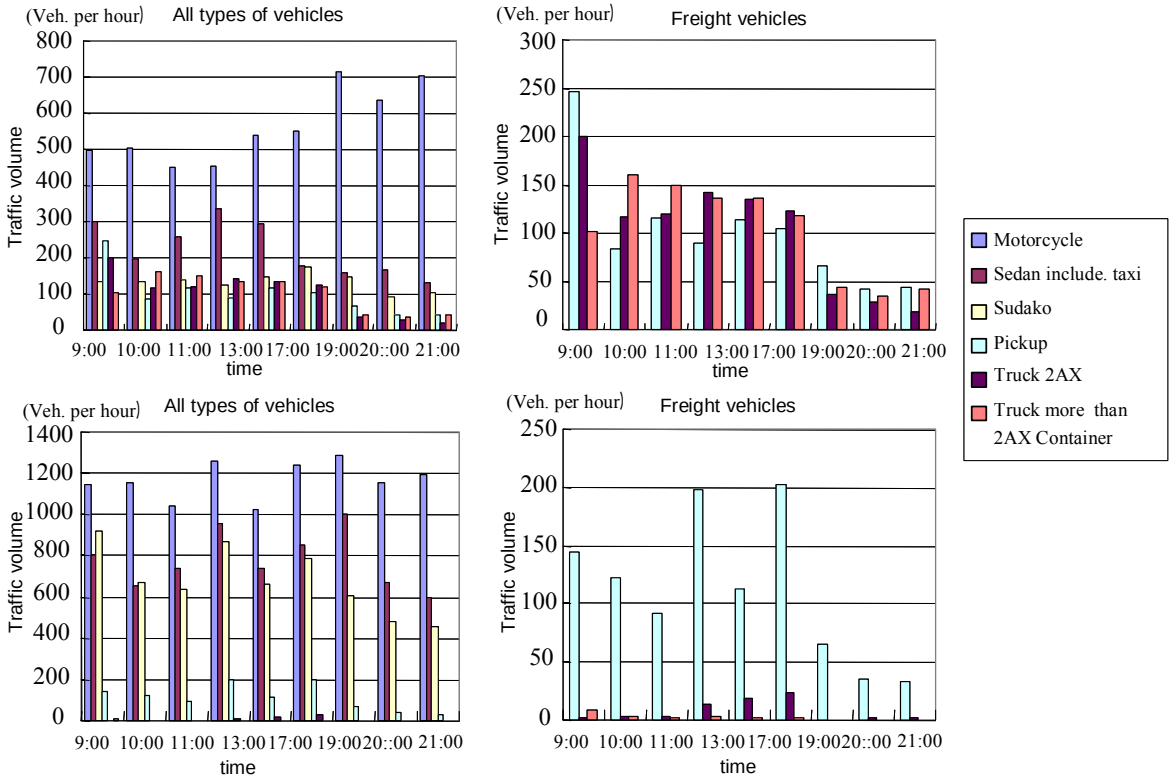

Figure 6: Results of half-day traffic volume survey of the Point 2 and 8 in Figure 4 right

(upper-left: all vehicles at Point 2; upper right: freight vehicles at Point 2; lower-left: all vehicles at Point 8, lower-right: freight vehicles at Point 8)

that the middle and the large size trucks run at the Point 2 whereas the most of trucks running at the Point 8 are pickup trucks. This means that the small trucks are used for the goods transport from suburban areas to the commercial area of city center whereas the middle and the large trucks are used for the goods transport to the industrial area of northern part of city. Since the large-size truck has been prohibited from entering the central area since August 1, 2004, this regulation may influence the behaviors of freight vehicles entering the city center. However, most of truck driver do not know this regulation according to our interviews to truck drivers, so it is sceptical that this regulation causes the results. The Figure 6 shows that the modal share of motorcycle is quite large at both points. The modal share of "sudako" is larger at the Point 8 than at the Point 2. This may mean that "sudako" is mainly used for the short travel inside the city center.

3.5 Interview survey to business companies on goods transport

We conducted the interview survey to business companies in the purpose of collecting the data of generation of goods and freight vehicles from enterprises in Medan city. The survey started on December 7, 2004 and ended on December 14, 2004. In the survey, the interviewers visited the enterprises and interviews to managers of the enterprises by asking questions. As the results of this survey, we successfully collected 145 sample data of enterprises. The share by size and the share by types of business of sample enterprises are shown in Figure 7 and Figure 8, respectively. The result shows that 87%

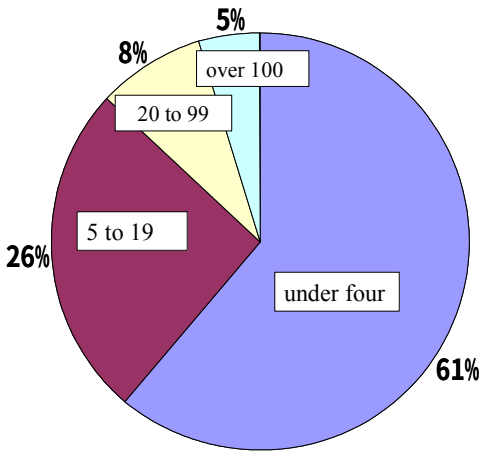

Figure 7: Share of size of sample enterprises

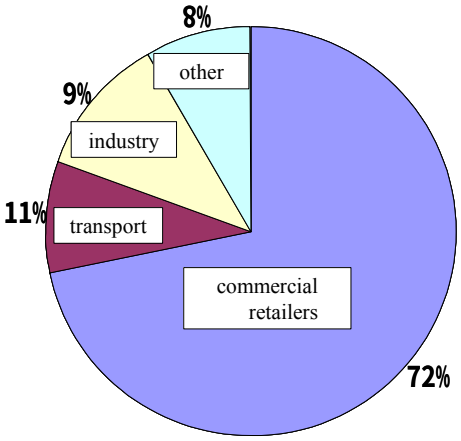

Figure 8: Share of business type of sample enterprises

Table 2: Distribution of types of vehicles owned by sample enterprises

type of vehicle	one	two	over three
pickup truck	75	15	5
two-axel truck	8	7	6
over three-axel truck	6	2	3

Table 3: Frequency of generation and average load factor of freight vehicles of sample enterprises

size of enterprises	frequency of generation (time per week)	average load factor (%)
less than four	2.11	29
over four	2.43	76

of total sample enterprises are small or middle size. This result is not so different from the results of preparatory survey on the distribution of number of companies by its size. The distribution of vehicle ownership of sample enterprises by types of vehicle is shown in Table 2. This shows that 87.6% of sample enterprises have at least one truck and that most of sample enterprises own the small-size trucks.

Next, the frequency of freight vehicle generating from the enterprises and the average load factor of freight vehicles are shown in Table 3. This shows that although the generating frequency is not so different between small enterprises and large enterprises, the average load factor of freight vehicles of larger enterprises are about 2.6 times larger than that of smaller enterprises. This means that the larger enterprises may manage the goods transport more efficiently than smaller enterprises.

4. FREIGHT TRAFFIC FLOW MODEL OF MEDAN

We develop the freight traffic flow model for the simulation of urban policy by using the results of survey shown in chapter 3.

4.1 Zones and road network in the analysis

We set the zones and the road network for developing the freight traffic model of Medan. The Development Zones (WPP) which is used in the urban planning of Medan city is basically applied to the analysis. This zoning is not equal to the administrative zoning of Medan city (BWK), but we judge that the Development Zones are more suitable to analyze the commercial activities. Five zones are set in Medan city shown in Figure 9. Then the representative nodes are set for all zones. In addition to the representative

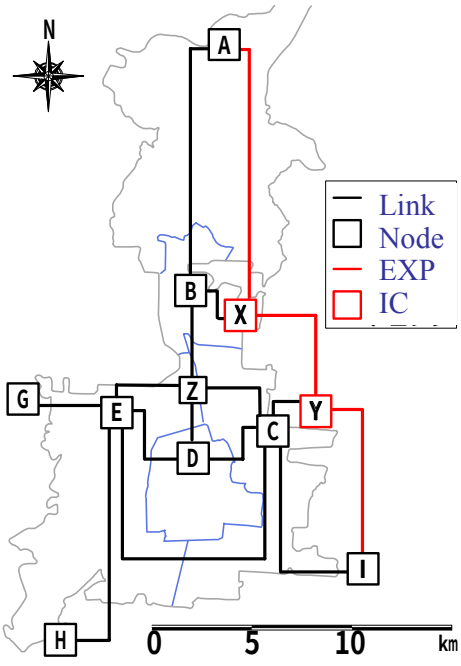

Figure 9: Zones and road network for the analysis

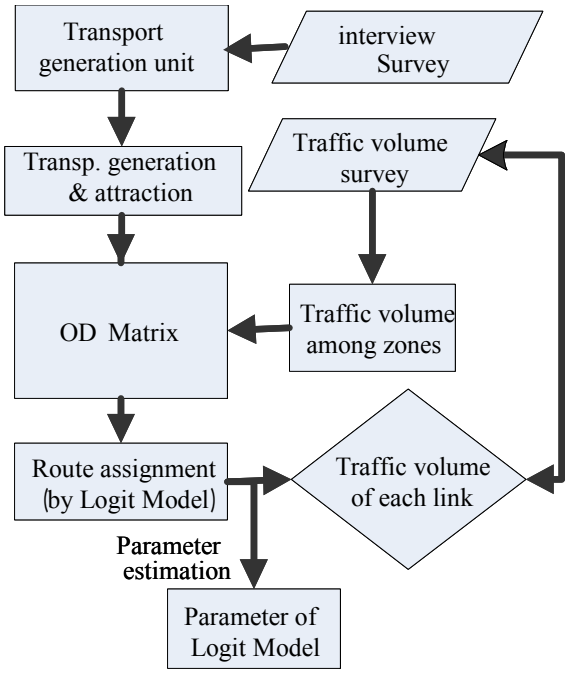

Figure 10: Process of development of freight traffic flow model of Medan

nodes, the interchanges of expressway and the points of major roads on the city borders are also set as the nodes of road network. Then, the real road network is simplified for the analysis by connecting the representative nodes.

4.2 Outline of the freight traffic flow model

The process of developing the freight traffic flow model is shown in Figure 10. First the origin-destination freight traffic demand matrix is estimated based on the collected statistical data and the results of our survey shown in chapter 3. Then, the route choice model is estimated by minimizing the difference between the simulated link flows and the observed link flows.

Generating unit of freight traffic from enterprise

We estimate the unit traffic volume of generation by type of vehicle, by size of enterprise and by type of business. The unit is estimated by calculating the average frequency of generating freight vehicles based on the results of interview survey to business enterprises. The estimated unit traffic volume is shown in Table 4.

Generation of traffic volume from zones

We estimate the number of enterprises of each zone by type of business and by size of enterprise based on the results of our survey on the distribution of number of companies by its size in Medan and the existing statistical data. Then we estimate the freight traffic volume generating from each zone by type of vehicle by multiplying the generating unit of freight trucks. The traffic volumes observed at the border points are used for the nodes located at the outside of Medan city.

Estimation of origin-destination matrix

We estimate the zone-based origin-destination traffic flow matrix by using the distribution of destination of freight vehicles generating from local enterprises, which is estimated based on the results of the interview survey of local enterprise. In this estimation, the Flator method is used under the condition that the generating volume from a zone is equal to the attracting volume into the zone.

Table 4: Generating unit of freight truck from enterprises used in the model

type of business	size of enterprises	pickup	2AX	over 2AX
retailers	very small	0.25	0.00	0.00
	small	0.22	0.04	0.00
	middle	0.14	0.00	0.29
	large	0.00	0.00	7.00
industry	very small	0.26	0.03	0.03
	small	0.04	0.20	0.20
	middle	0.38	0.48	0.19
	large	0.10	0.38	1.88
transport and others	very small	0.25	0.00	0.00
	small	0.03	0.29	0.07
	middle	0.83	1.68	1.65
	large	0.19	0.71	0.67

Route choice model

First, the three routes are selected as an alternative route set for all pairs of an origin zone and a destination zone based on the results of interviews to local drivers. Then, the aggregate logit model is applied to the route choice behavior of truck drivers shown as:

$$P_{k,i}^{od} = \frac{\exp(-\theta V_{k,i}^{od})}{\sum_j \exp(-\theta V_{k,j}^{od})}$$

where $P_{k,i}^{od}$ is the probability of choosing i-th route by a truck driver running from a zone o to zone d by k-th type of vehicle (K={pickup, 2AX and over 2AX}, $V_{k,i}^{od}$ is the utility of route and θ is the unknown parameter of the error variance.

The utility of route is defined as the linear function of travel time and travel cost of OD pair as follows,

$$V_{k,i}^{od} = \omega_k \cdot T_{k,i}^{od} + C_{k,i}^{od}$$

where $T_{k,i}^{od}$ is the travel time, $C_{k,i}^{od}$ is the travel cost and ω_k is the value of time of k-th type of freight vehicle. The travel cost is defined by summing the fuel cost which is in proportion with distance and the expressway charge. The travel time of OD pair is assumed to change by the traffic congestion of routes. The BPR function is used for expressing the link performance, that is

$$t_a = l_a \Big/ v_a \left(1 + \beta \left(x_a \Big/ Cap_a \right)^{\gamma} \right)$$

where t_a is the travel time of link a, l_a is the length of link a, v_a is the vehicle speed of free running, Cap_a is the road capacity of link a and x_a is the traffic volume of link a. The parameters of BPR function are set as $\beta = 0.5$ and $\gamma = 1.5$ according to the previous researches.

Estimation of unknown parameters

The unknown parameters of the route choice model are summarized into θ of the logit model and ω_k of the value of time. In addition to these parameters, we add two other parameters: one is the parameter for the large-truck expressway-use dummy variable that is equal to 1 if the large truck uses the expressway and 0 otherwise; and the other is the parameter for the large-truck CBD-passing dummy variable that is equal to 1 if the large truck enters CBD zones and 0 otherwise. We calibrate the unknown parameters by minimizing the difference of the observed link traffic volumes and the simulated link traffic volumes. In this calibration, the other types of vehicle than freight vehicles are assumed to be fixed as the observed traffic volume. The result of the calibration is shown in Table 5. This shows that large trucks tend to use the expressway more than middle and small trucks and that large trucks tend not to pass the city center. The value

Table 5: Results of calibration of unknown parameters of the model

variables	parameters
θ in logit model	0.547
dummy of use of expressway by large truck	3.94
dummy of entering CBD by large truck	-7.03
value of time of large truck	1.16
value of time of middle truck	0.43
value of tiem of small truck	0.48

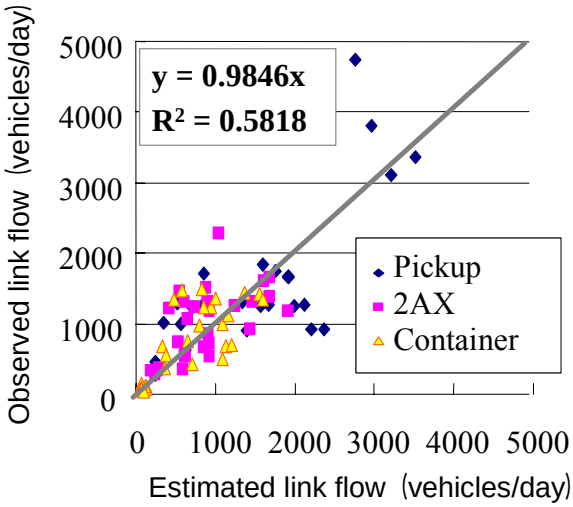

Figure 11: Estimated link flow vs. observed link flow

of time of large trucks is larger than that of small and middle trucks. The comparison between the estimated link flow and the observed link flow is shown in Figure 11.

5. SCENARIO ANALYSIS FOR RELOCATION OF POLONIA AIRPORT

We analyze the development policy for the relocation of the Polonia airport by using the freight vehicle flow model.

5.1 Basic conditions of the analysis

The Polonia airport is planned to be relocated to the suburban area from the current location which is close to the CBD due to the lack of airport capacity. Although the land-use of the airport area after the relocation has not yet been decided officially at this moment, the land-use of 2 km^2 area could impact the future urban structure seriously.

Therefore, we analyze the following two scenarios about the land-use of the area:

Scenario 1: development of the commercial area

As the land-use density of the CBD close to the airport has already reached almost saturation due to many commercial facilities, the pressure of expanding the CBD is very strong. So if any regulation of land-use is not introduced into the ex-airport area, it is highly expected that the area will be redeveloped by developers into the similar commercial area as existing CBD if Medan city keeps the high economic growth. Then, in this scenario, we assume that the downtown area with the same commercial density as the current CBD will be realized.

Scenario 2: development control

Just few open space such as public parks have been installed now in the center of Medan city except the open space in front of central railway station. This may cause the lack of urban amenity. For the sustainable development of the city, the installment of new open space at the ex-airport area can be one of the most effective policy options. People can enjoy the comfortable life by the leisure activity at the area. Then, in this

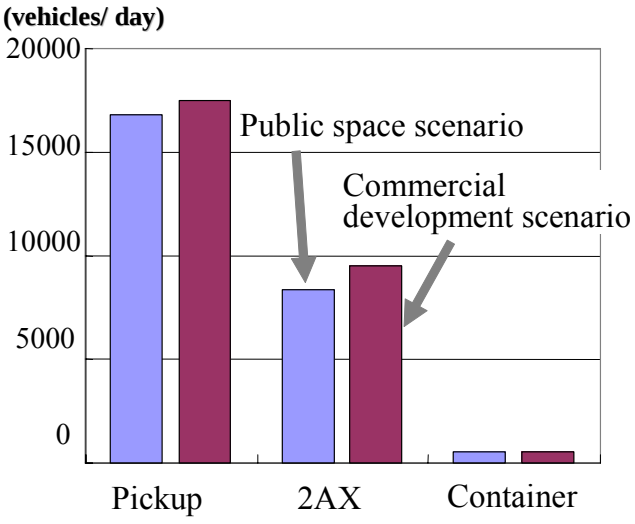

Figure 12: Comparison of simulated results of traffic volume of CBD between two scenarios

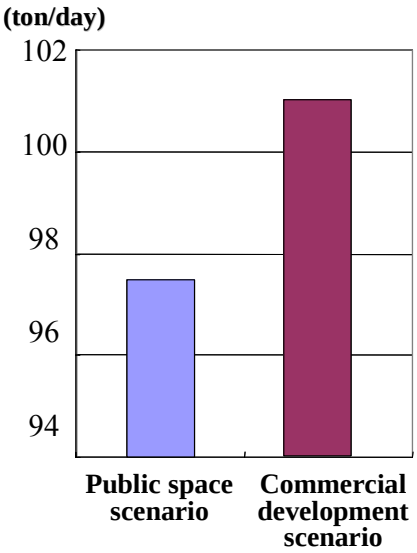

Figure 13: Comparison of simulated results of CO2 emissions from freight vehicles between two scenarios

scenario, we assume that the open space will be developed at the area close to the CBD.

5.2 Results of scenario analysis

The freight traffic flow model is applied to the scenario analysis. We assume that the passenger transport is not impacted by the scenarios though it should be affected by the development of the area because the model cannot cover them. In this analysis, we estimate the CO_2 emission from the freight traffic in addition to the traffic flow simulation. The emission unit of CO_2 used in this simulation is referred to the emission unit by types of vehicle and by vehicle speed, which was estimated in the analysis at the Metro Manila. Although it is sure that the emission unit of Medan should be different from that of Manila because the maintenance technology of vehicles and the average age of vehicles are different between two cities, we decided to use them due to the lack of data of Medan. The results of simulated traffic volume of freight vehicles running at the center of city and simulated amount of CO_2 emitted from freight vehicles are shown in Figure 12 and Figure 13, respectively. These results show that the traffic volume and amount of CO_2 emission of the commercial development scenario is larger than that of the open space scenario by about 8%. This may cause the serious traffic congestion in the CBD area. Therefore we can conclude that the land-use policy impacts quite significantly the urban traffic and the urban environment. The careful discussion on the land-use of the area after relocation of the airport is highly required.

6. CONCLUSIONS

In this research, we surveyed the goods transport of Medan city, one of the middle-size developing cities. Then we developed the freight traffic flow model based on the collected data in the survey. Finally we analyze the future scenarios of the land-use of the area after the airport is relocate by applying the model.

First, we showed the feasibility of collecting data of goods transport by the small-scale survey for the middle-size city with population of two million. However, on the contrary, we found some limitations of the method. Although we had prepared carefully the

survey and communicated with local staffs in advance as much as possible, we still needed to change our plan in the process of survey. Actually, we found many know-how of local survey through the experience of our survey and brushed up the knowledge into the techniques based on the know-how. Therefore, this valuable experience should be recorded for the further research in Medan.

Next, we successfully developed the model which can simulate the freight traffic flow in Medan city. This model is so universal that it can be applied to the other city. The accuracy of the model may not be high enough to analyze the detailed countermeasures against specific transportation problems because the model is based on the quite limited sample data. However, it is still useful to discuss the future rough direction of transportation policy in such a scenario analysis as the example shown in chapter 5. Moreover, the model may be valuable for local people to understand the mechanism of impact of a specific transportation policy. In this sense, this type of analytical model could be beneficial from the educational viewpoint as well.

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