Model of Municipal Solid Wastes Transportation Costs Type Dump Truck (Case Study at The Malang City, Indonesia)

Burhamtoro[1)], Achmad Wicaksono[2)], M. Bisri[3)], Soemarno[4)]

e-mail: [1)]goes_bur@yahoo.com

***Abstract*-- The increasing volume of municipal solid waste resulting in the rising of frequency and transportation costs on the temporary disposal station is called TPS to Landfill (TPA).This recent study is to examine the cost model based on the speed of the vehicle transporting waste using Dump Truck types from TPS to TPA with various brands of vehicles. This study applies survey method in which the researchers investigate the distance, time and volume of the waste transported by the entire fleet. The results of Model Municipal Solid Waste Transportation Costs obtained equation: $Y = 7{,}66x^2 – 580{,}81x + 15454{,}79$. Y variable indicates the transportation cost (Rupiah/m^3) and X variable points out the speed (km/ h). Cost of transporting waste to urban areas at optimum speeds obtain 37.91 Km/hour with minimum waste transportation costs Rp 4.445, -/m^3.**

***Index Term*-- Municipal Solid Waste, speed of vehicles, Transportation Costs**

I. INTRODUCTION

Volume of the municipal solid wastes that are likely to gradually increase and accumulate resulting in any environmental pollution problems at temporary disposal station (TDS) (Saxena, 2010). The investigation demonstrates that the inhabitants of Malang city produces the household wastes averagely reach up to 301.788 m^3 per day. It, however, can be transported only 222.107 m^3 per day. If the waste problem's are not addressed, consequently the sheer volume of the waste is constantly getting larger in TDS.

The previous studies in 2010 indicated that there were 47.18% of the waste evidently transported in District Klojen, 45.38% in District Sukun, 34.8% in District Kedungkandang and 46.04% District Blimbing (Burhamtoro, 2012). This remarkable study showed that there is a need to solid the waste transporting services in Malang city as required in relation to the public work ministers act no 21/PRT/M/2006 and the national development policies and setrategic waste management systems (KNSP-SPP). The rule and regulation introduced govern up to 70% in achievement.

The cost of waste collection consists of two types i.e: direct and indirect costs. The direct cost refer to all direct expenditure incurred in managing solid wastes in the certain area. It also includes the resources used in the administration, development and operations of waste management right from storage to collection, transportation and disposal. Conversely, indirect costs refer to external cost incurred in operating the existing waste management system. These costs include the environment damage cost of hazard storage, and collection disposal practices (Sakawi, 2011). According Apaydin (2007), cost of transporting waste reach up to 85% of the total expenditure of waste management. Based on the percentage of required transport efficiency, transport costs can thus be optimized.

In general, weight of goods transported becomes one of an important elements in calculating the transportation cost. The traffic condition consideration, however, has not put into perspectives yet. Therefore, the existing traffic conditions need to be taken into consideration in allocating budget of the waste transportation.

Transporting waste is an operation at activity started from the point of final point of the collection cycle to a landfill or TPST on collecting the individual patterns of direct or spot removal (Depo Transfer, transfer station), the temporary disposal station (TPS, LPS, TPS 3R) or final disposal (landfill / TPST).

Corresponding to this activity, transporting methods and equipment to use depends on the usage of collecting method. Center for Water and Sanitation Engineering Region 2 Surabaya, the Competency Based Training Materials Waste Division, stated that the problems faced in transporting waste are as follows: The working hours are inefficient;the use of the loading capacity of the vehicle is incapable the route is inefficient; the behavior of officers and accessibility are unfavorable.

Transporting trash by using the dump truck is called a stationery container system (SCS).The system is a fixed container collection system where waste storage container is left at the point of decision. The workings of the container system remains as Fig. 1.

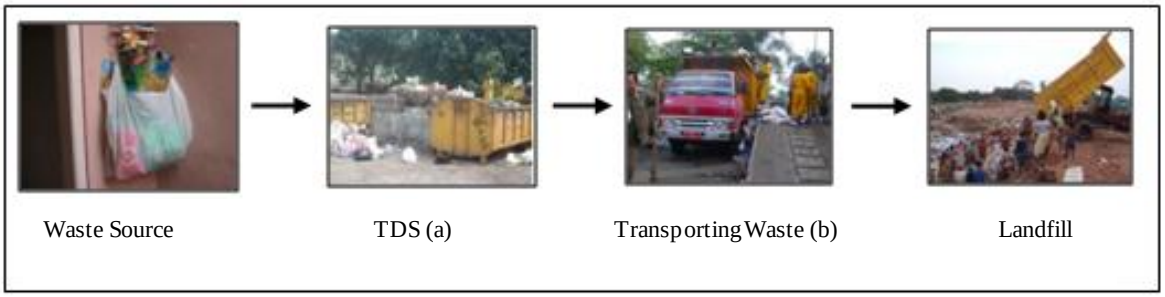

Fig. 1. Waste transportation with SCS system

The following sequences explain how the stationery container works; waste storage container is left at the point of decision (a). Waste is transferred into the garbage trucks manually or being assisted by mechanical equipment available on the trucks (b), which subsequently transported to the landfill. After processing the disposal activity in a landfill, the truck returned to the polls if required. The drum trucks are back to the pool when the carriage has completed.

The estimation of freight costs are calculated based on the cost of transportation in the act of transporting activities. Basically, the cost of transportation is the amount of money that must be paid by the transportation service provider to perform transportation services for both fixed costs (infrastructure) and variable costs (operation). These costs depend on a variety of conditions applied such as geographical factors, infrastructure, administrative boundaries, energy, and how they were brought (Sofyan M., 2009).

There are three ways to put the importance of wise expenses in perspective in ways by examining 1) transportation costs are associated with the value of the goods being moved; 2) transportation costs are related to other known barriers to trade, like tariffs; and 3) the extent to which transportation costs alter relative prices. (Hummels, 2007)

The method of transporting waste calculation cost uses a statistical approach to the value of multiple regression approach. Waters (1997) describes different methods for estimating the cost of the relationship between output and costs. One method that has been used in the study is the statistical method of transporting costs. In this method, the relationship between the output and the cost is estimated by using different statistical techniques. Multiple regression analysis showed how costs are changing if one of the variables is changing as well.

While the variables used in calculating the transport costs include fixed costs and variable costs. Fixed costs are costs that are calculated which the outcomes can not be changed. While the variable costs divided into 5 (five) parts. They are as follow: the cost of tires; fuel; maintenance costs; labor costs; and total variable costs (Mark Berwick and Moh. Farooq, 2003).

The vehicle speed influences the amount of the "variable costs" in transporting wastes to the disposal location. The definition of vehicle speed used in this context refers to the value of the vehicle movement in the distance per unit of time, expressed in units of km / h, covering instantaneous speed, the speed of moving and travel speed (Arifin, 2007). In calculating the cost of transporting waste, the variable speed used drive speed (Speed Journey), obtained from the division between the mileage traveled by the vehicle during the service time process of waste transportation (Burhamtoro, 2012).

Vehicle operating cost (VOC) is the sum of the cost of fuel, cost of engine lubricants, tire costs, maintenance costs, depreciation costs, interest rates, insurance costs, driver wages and overhead, each influenced by the speed of the vehicle which is the variable cost per 1,000 km (Yanagiya, 1990). In contrast, Lavinson (2005) and Sugiyanto (2011) argue that the calculation of variable costs per km. Fixed costs include vehicle tax, accident insurance, and a physical test vehicles accounted for in a single year (Burhamtoro, 2012).

The scope and limitations of this research are all municipal solid waste hauler dump trucks that serve Malang city in period of february 2012 until to december 2012.

II. RESEARCH METHOD

The primary data was collected in a way by riding the garbage hauler on vehicles (on board) type Dump Truck. The secondary data was obtained from the results of previous studies. The primary data was obtained in the form of distance, time and volume of household waste in the process of transporting waste from Pool-TPS-TPA andreturning way to the pool. If the volume of waste exceeds the capacity of the truck, the transport process is done several times from TPS to landfill.

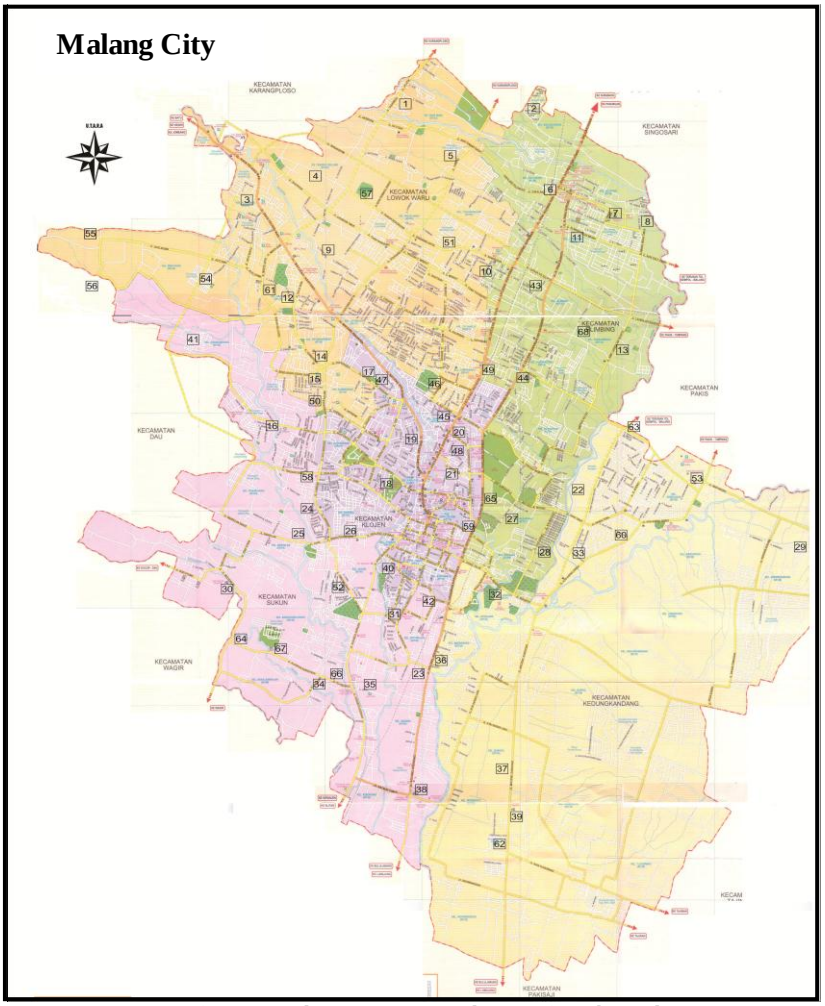

Fig. 2. TDS (Temporarily Wastes Disposal Station) in the Malang City

The variable and fixed costs underlie the method in calculating the vehicle operating costs required by each vehicle. The length of the route influences the variable costs which is inapplicable to fixed costs. Fixed costs are calculated based on the value of the vehicle tax, compulsory contributions, and feasibility testing of vehicles divided by the number of working days.

TABLE I
The formula for variable costs

NO.	PARAMETER	FORMULA	INFORMATION
1	Fuel Consumption	$(0{,}06427V^2 - 7{,}0613V + 318{,}3326)$ x Fuel Price	Fuel Cosumption (liter/1000km)
2	Engine Oil Consumption	$(0{,}00048V^2 - 0{,}05608V + 3{,}07383)$ x Oil Price	Engine Oil Cosumption (liter/1000km)
3	Tire Wear	(0,0011553V - 0,0059333) x Tire price x n Tire	Total Tire wear of vehicle equated as wear of one tire per 1000 kilometers
4	Maintainance cost on parts	(0,0000191V + 0,00154) x Vehicle Price	Maintanace parts equated as the depreiciable value of the vehicle per 1000 kilometers
5	Maintainance cost of labor	(0,01511V + 1,212) x Labor wages per hour	Hours of maintanace labor per 1000 kilometers
6	Depreciation	(1/(6,129V + 245)) x Vehicle Price	Depreciation per 1000 kilometers
7	Interest	((0,12 x 1000)/(1750V)) x Vehicle Price	Interset per 1000 kilometers
8	Insurance	((0,06x1000x0,5)/(1750V)) x Vehicle Price	Insurance cost per 1000 kilometers
9	Traveling Hours for Wages	(1000/V) x Driver Wages	Traveling time per 1000 kilometers
10	Overhead	Sum of Costs x 10%	

Information: V = Vehicle Speed (km/hours)
Source: Yanagiya, 1990

III. RESULT AND DISCUSSION

In calculating the vehicle operating cost (VOC), the speed of the vehicle is one of the significant factors in determining variables (Yanagiya, 1990). The divide outcome between travel distance and travel hour services indicate the speed of

the vehicle as shown in Table II. While the volume of waste transported is obtained from the average volume of each type of waste dump truck type vehicle over a period of time certain observations.

In terms of the different speed of the used vehicles, Table II demonstrates that the Toyota Dyna brand BY 43 indicates the highest speed vehicle which reaches 19.182 km / h. In contrast, the Diesel Cold shows the lowest speed one that is 22.603 km / h. To the volume of waste transported, New WU Toyota vehicle has the smallest volume of 12.977 m3. In opposite, the Toyota Dyna BU 343 has largest capacity of 19.336 m^3.

VOC calculations for various types of Dump Truck were obtained by applying the Yanagiya method (1990). The maximum speed of vehicles permitted in the city which is 50 km / hour (Decree No. 14, 2006) results in the various speed of vehicles used.

In terms of the different speed of the used vehicles, Table II demonstrates that the Toyota Dyna brand BY 43 indicates the highest speed vehicle which reaches 19.182 km / h. In contrast, the Diesel Cold shows the lowest speed one that is 22.603 km / h. To the volume of waste transported, New WU Toyota vehicle has the smallest volume of 12.977 m3. In opposite, the Toyota Dyna BU 343 has largest capacity of 19.336 m^3.

VOC calculations for various types of Dump Truck were obtained by applying the Yanagiya method (1990). The maximum speed of vehicles permitted in the city which is 50 km / hour (Decree No. 14, 2006) results in the various speed of vehicles used.

TABLE II
Vehicle Speed and waste volume by each brand of vehicles

NO	TPS	TYPE VEHICLE	DISTANCE (km)	TIME (Menit)	SPEED (Km/Jam)	SPEED EACH TYPE (Km/Jam)	WASTE VOLUME (m3)	WASTE VOL. EACH VEHICLE (m3)
1	2	3	4	5	6	7	8	9
1	CIANJUR (TMP)	DUMP TRUCK COLD DIESEL	40,63	97,73	24,94	22,603	17,30	15,777
2	SUMBERSARI	DUMP TRUCK COLD DIESEL	35,57	84,03	25,40		16,52	
3	ASAHAN (PENJARA)	DUMP TRUCK COLD DIESEL	50,79	131,84	23,11		11,27	
4	STD BLIMBING	DUMP TRUCK COLD DIESEL	38,39	104,59	22,02		14,82	
5	RAMPAL CELAKET	DUMP TRUCK COLD DIESEL	24,88	71,11	20,99		11,15	
6	MANYAR	DUMP TRUCK COLD DIESEL	25,41	79,62	19,15		23,61	
7	SERAM	MP TRUCK T. NEW W U 342 R TKMQ /	28,87	94,93	18,25	20,344	21,80	12,977
8	MUHARTO	MP TRUCK T. NEW W U 342 R TKMQ /	34,33	93,33	22,07		9,21	
9	RY. LANGSEP	MP TRUCK T. NEW W U 342 R TKMQ /	34,33	99,43	20,72		7,92	
10	BOROBUDUR	TOYOTA DYNA BU 343R	52,46	174,88	18,00	20,714	16,91	19,336
11	SULFAT	TOYOTA DYNA BU 343R	39,62	141,72	16,77		16,73	
12	TPS. KARTINI	TOYOTA DYNA BU 343R	19,53	42,82	27,37		24,37	
13	TAWANGMANGU	TOYOTA DYNA BY 43 LONG/490061	45,84	130,25	21,12	19,182	21,28	17,333
14	BENTOEL	TOYOTA DYNA BY 43 LONG/490061	20,79	68,55	18,20		12,71	
15	ASAHAN (PENJARA)	TOYOTA DYNA BY 43 LONG/490061	46,61	147,71	18,93		24,19	
16	ORO-ORO DOWO	TOYOTA DYNA BY 43 LONG/490061	21,87	71,01	18,48		11,15	

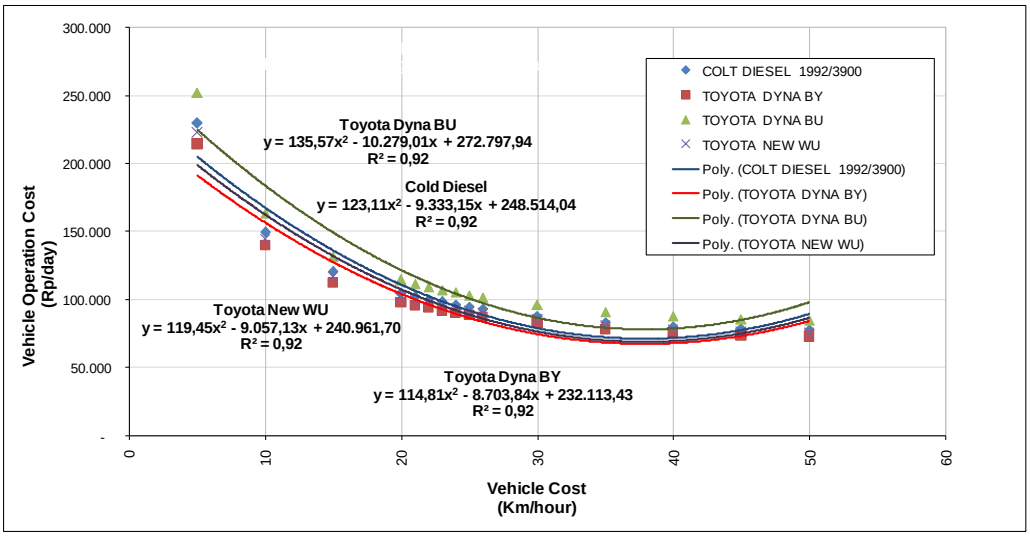

Fig. 3. Relationship between the VOC (vehicle operating cost) and the VC (vehicle cost).

Figure 3 shows that each vehicle has a different amount of operating costs because of the nature of the price of its vehicle. For each vehicle formula can be described as follows: At Colt Diesel brand vehicles obtained equation Y = 123,11 x^2 – 9333,15x + 248514,04 with R^2 value 0.92. For vehicles Toyota Dyna BY obtained equation Y = 114,81x^2 – 8703,84x + 232113,43 with R^2 0.92. As for the brands of Toyota Dyna BU and Toyota New WU has the equation Y = 135,57x^2 – 10279,01x + 272797,94 and Y = 119,45x^2 – 9057,13x + 240961,70 with R^2 values of each 0.92. Where in the equation Y is the vehicle operating cost and X is the speed of the vehicle. For the optimum speed of each vehicle brands can be seen in Table III.

TABEL III

VOC minimum value with optimum speed of each vehicle type

TYPE DUMP TRUCK	EQUATION	OPTIMUM SPEED (Km/H)	MINIMUM COST (Rp/day)
COLD DIESEL	$123{,}11x^2$ - 9.333,15x + 248.514,04	37,91	71.624
TOYOTA DYNA BY	$114{,}81x^2$ - 8.703,84x + 232.113,43	37,91	67.152
TOYOTA DYNA BU	$135{,}57x^2$ - 10.279,01x + 272.797,94	37,91	77.958
TOYOTA NEW WU	$119{,}45x^2$ - 9.057,13x + 240.961,70	37,91	69.276

Table III demonstrates the optimum speed of each vehicle which is 37.91 km / h. The Toyota Dyna BY, the most economical operational vehicles, costs Rp 67,152 / day. On the one hand, the Toyota Dyna BU which is the most costly vehicles in operation, charges Rp 77,958 / day.

Relationship with vehicle speed operating costs Dump Truck type as in Fig. 4.

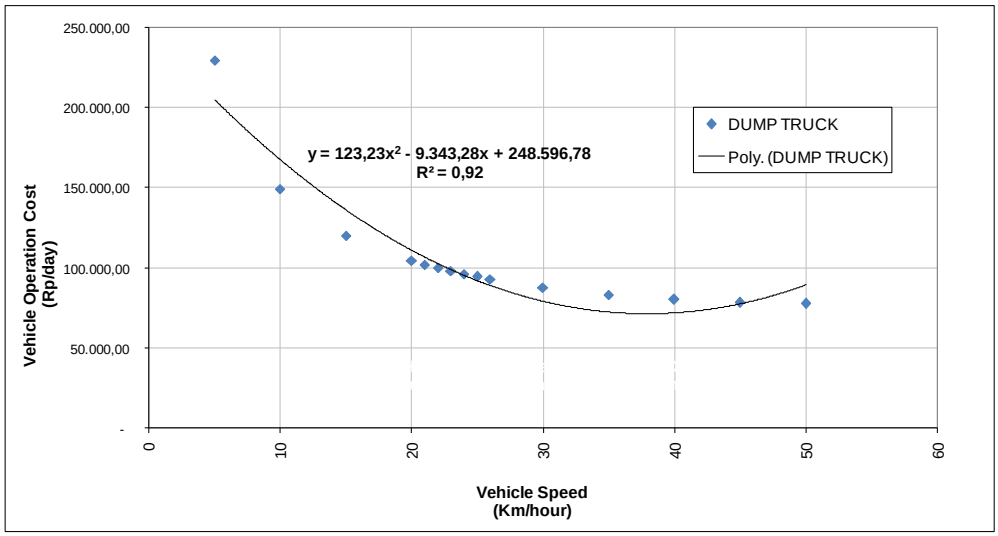

Fig. 4. Relationship between the VOC and the vehicle speed of Dump Truck.

The formula obtained is Y = $123{,}23x^2$ – 9343,28x + 248596,78, by the formula Y = ax^2 + bx + c the top of the parabola x (optimum speed) is at -b/2a and Y (minimum cost) is at $(b^2\text{-}4ac)/(-4a)$ (Anonymous, 2013), in order to obtain optimum speed 37.91 km / h with a minimum vehicle operating costs Rp 71.491, -/day.

The calculation of the cost of transporting waste by VOC is divided by the volume of waste transported. The relationship between speed with transportation costs can be seen in Figure 5.

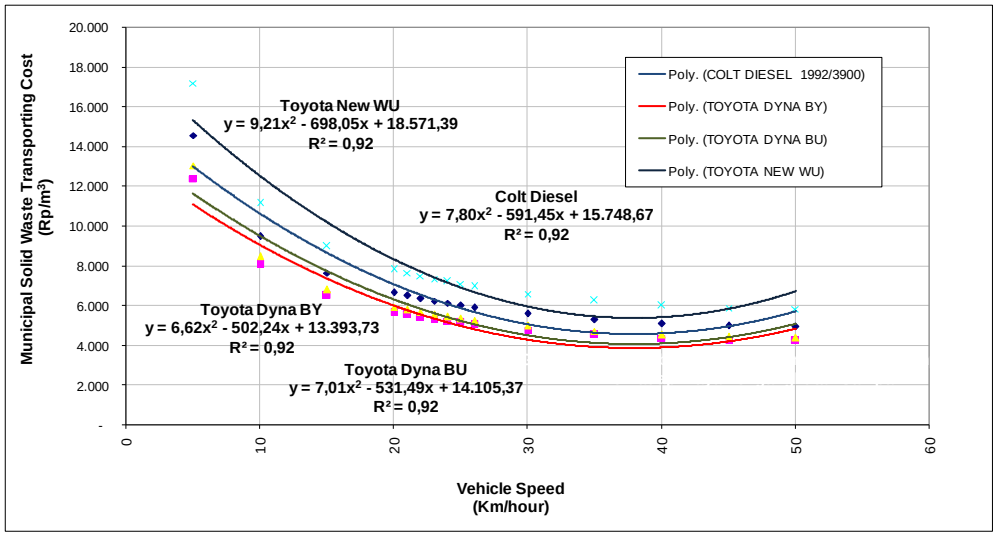

Fig. 5. Relationship between the transport cost of wastes and vehicle speeds of Dump Truck

Based on figure 5, For Colt Diesel vehicles obtained equation Y = 7,80 x^2 – 591,45x + 15748,67. As for the Toyota Dyna BY obtained equation Y = $6{,}62x^2$ – 502,24x + 13393,73, while the vehicle Toyota Dyna BU and Toyota New WU obtained equation Y = $7{,}01x^2$ – 531,49x + 14105,37 and Y = $9{,}21x^2$ – 698,05x + 18571,39. Y variable in the equation is the cost of transport per m^3, while the X variable is the vehicle speed in each equation with R^2 of 0.92. The minimum value for each vehicle transportation costs can be seen in Table IV.

TABLE IV
The optimum value of the transport cost at the each vehicle speed.

TYPE DUMP TRUCK	EQUATION	OPTIMUM SPEED (Km/Jam)	MINIMUM COST (Rp/M3)
TOYOTA NEW WU	$9{,}21x^2 - 698{,}05x + 18.571{,}39$	37,91	5.343
COLD DIESEL	$7{,}80x^2 - 591{,}45x + 15.748{,}67$	37,91	4.543
TOYOTA DYNA BY	$6{,}62x^2 - 502{,}24x + 13.393{,}73$	37,91	3.878
TOYOTA DYNA BU	$7{,}01x^2 - 531{,}49x + 14.105{,}37$	37,91	4.036

Table IV shows the optimum speed of each vehicle which appears 37.91 km / h. The Toyota Dyna BY is the cheapest freight vehicles pricing Rp 3,878 / m^3. Meanwhile the New WU Toyota is the most expensive one charging Rp 5,343 / m^3.

The calculation of the cost of transporting type vehicle Dump Truck freight costs based on the average of every type of Dump Truck. The model cost of transporting waste types like Dump Truck is as indicated in figure 6 below.

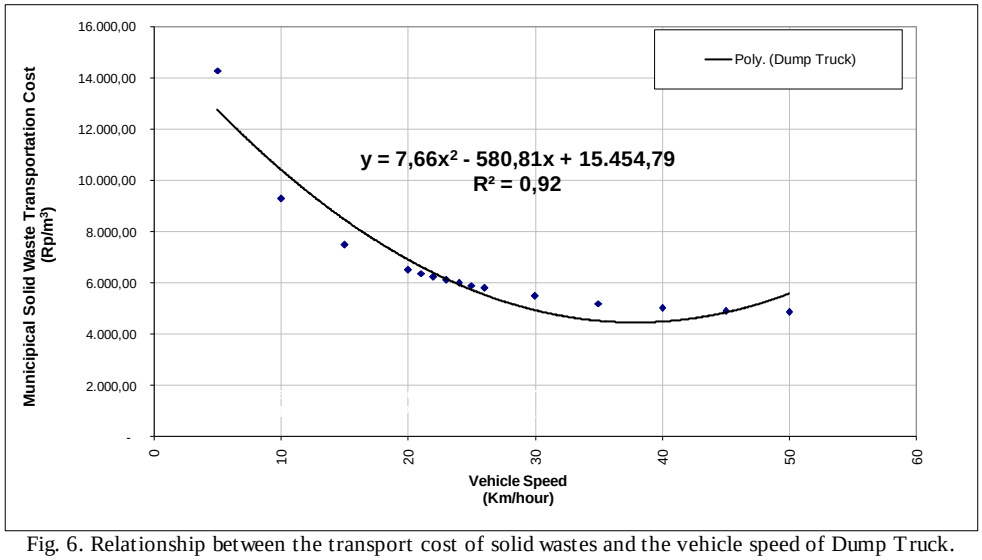

Fig. 6. Relationship between the transport cost of solid wastes and the vehicle speed of Dump Truck.

Based on the graph of the transportation cost with speed of Dump Truck, then the equation obtained Y = $7{,}66x^2$ – 580,81x + 15454,79 with the determination ratio of R^2 is 0.92 or good ratio, in order to obtain optimum speed 37.91 km/h with minimum transportation cost of Rp 4.445, -/m^3.

IV. CONCLUSION

The model of Municipal Solid Waste Transportation Cost (MSWTC) Dump Truck types have a formula: Y = $7{,}66x^2$ – 580,81x + 15454,79. The Y variable indicates the Transportation Cost (Rp/m^3), while the X variable points out the Vehicle Speed (km / h). The cost of transporting waste to urban areas at optimum speeds obtained 37.91 Km/hour with minimum waste transportation costs Rp 4.445, -/m^3.

The cost of transporting waste should consider the traffic conditions of the working areas inevitably affecting the vehicle speed. The further research related to the transport operating hours as well as the reduction of the volume of municipal solid waste is required.

REFERENCES

[1] *Anonymous*,"*Persamaan Kuadrat" (Quadratic equations)*, Wikipedia, 2013.

[2] Apaydin, O. and Gonullu, M.T, *"Route Optimation for Solid Waste Colllection:Trabzon (Turkey) Case Study*, Global NEST Journal 2007: 9(1):6-11, Turkey.

[3] Arifin, M. Z., *"Analisa Efektifitas Fasilitas Zebra Cross Pada Jalan MT. Haryono dan Jalan Gajayana"*, Jurnal Rekayasa Sipil, 2007; 1(1):13-24, Malang.

[4] Berwick Mark and Moh. Farooq,"*Truck Costing Model for Transportation Managers"*, Upper Great Plains Transportation Institute North Dakota State University,North Dakota, 2003.

[5] Burhamtoro, *"Optimizing of Transportation Municipal Solid Waste at Malang City"*. An Interdisciplinary Studies Seminar (ISS) in Natural Resources and Environmental Management, Graduate School, University of Brawijaya, pp.77-78, Malang, July 2012.

[6] Burhamtoro, "Biaya angkut Hauled Container System (HCS) dan Stationery Contaioner System (SCS) Pada Pengangkutan Sampah Rumah Tangga (Studi Kasus: Kecamatan Blimbing Kota Malang)", Prokons Jurnal Teknik Sipil, Volume 6 Nomor 1 pp. 26-37, Malang, 2012.

[7] Hummels, David,"*Transportation Costs and International Trade in the Second Era of Globalization"*, Journal of Economic Perspectives, 21. pp. 131–154, Indiana Amerika, 2007.

[8] Yanagiya, Kensuke,"*Feasibility Study on The Cikampek-Cirebon Toolway Project"*, Japan International Coorporation Agency, Jakarta, 1990.

[9] Lavinson, D, "*Operating Costs for Trucks"*, Twin Cities: Department of Civil Engineering University of Minnesota, Minnesota, 2005.

[10] Sofyan, M. Saleh, "*Pengaruh Muatan Truk Berlebihan Terhadap Biaya Pemeliharaan Jalan"*, Jurnal Transportasi, 9, Bandung, 2009.

[11] Saxena, Shikha, "*Sustainable Waste Management Issues in India"*, The IUP Journal of Soil and Water Sciences. III (1):72-90, India, 2010.

[12] Sugiyanto, Gito,"*Estimation of Congestion Cost of Motorcycles Users in Malioboro, Yogyakarta, Indonesia"*, International Journal of Civil & Environmental Engineering (IJCEE-IJENS),11(01):56-63,Yogyakarta, 2011.

[13] Widiarto Achmad, "*Evaluasi Sistem Pengangkutan Sampah Di Kota Malang*" (Evaluation of the Solid Wastes Transportation System in Malang City), Master Theses, Environment Engineering, Institut Teknologi Sepuluh Nopember, Surabaya, 2012.

[14] Peraturan Menteri Pekerjaan Umum No. 21/PRT/M/2006 tentang *Kebijakan dan Strategi Nasional Pengembangan Sistem Pengelolaan Sampah (KNSP-SPP)*.

Burhamtoro; He is an Associate Professor in Civil Engineering Department, State Polytechnic of Malang, Jln. Soekarno Hatta no. 9 Malang, East Java, Indonesia.
Phone/fax: +62 341 471933.
E-mail: goes_bur@yahoo.com

Now, He is a Ph.D Candidate, Evironmetal Sciences and Technology Graduate Program, in the Graduate School, University of Brawijaya, Jln. MT. Haryono 167, Malang, Indonesia. Phone/fax: +62 341 577200.

He was born in Yogyakarta, Indonesia on 11th September 1959. His education level at elementary school, junior/middle high school, and senior high school were experienced in Yogyakarta Region. He got graduate program in Education Civil Engineering (Drs.) from State Yogyakarta University, Yogyakarta, Indonesia from August 1979 until September 1983, and graduate in Civil Engineering (ST) from Muhamadiyah University, Malang, East Java, Indonesia from August 1991 until September 1993. He received his Master in Transportation (MT) from Institute Technology Sepuluh November (ITS), Surabaya, East Java, Indonesia from August 1999 until March 2002.

Ir. Achmad Wicaksono, M. Eng., Ph.D.; He is an Associate Professor in Civil Engineering Department, Faculty of Engineering, Brawijaya University, Jl. MT. Haryono 167, Malang, Indonesia. Phone/fax:+62 342 577200.
E-mail: wicaksono1968@yahoo.com
His academic experience is:
- Doctor of Philosophy (Ph.D), Transport Engineering, The University of Tokyo, Japan, 1998.
- Masters of Transportation (M. Eng), Transport Engineering, Asian Institute of Technology, Bangkok, Thailand, 1995.
- Bachelor of Science (Ir.), Civil Engineering, Brawijaya University, Malang, East Java, Indonesia, 1990.

Prof. Dr. Ir. M Bisri, MS; His current address is in Water Resources Engineering Department, Faculty of Engineering, Brawijaya University, Jl. MT. Haryono 167, Malang, Indonesia. Phone/fax:+62 342 577200.
E-mail: mohammadbisri@yahoo.com
His academic experience is:
- Doctor of Philosophy (Dr.), Water Resources Engineering, Brawijaya University, Malang, East Java, Indonesia, 2006.
- Masters of Science (MS), Soil and Water Management, Gajahmada University, Yogyakarta, Indonesia, 1990.
- Bachelor of Science (Ir.), Water Engineering, Brawijaya University, Malang, East Java, Indonesia, 1984.

Prof. Dr. Ir. Soemarno, MS; His current address is in Environmental Studies Graduate Program, Graduate School, University of Brawijaya, Jl. MT. Haryono 167, Malang, Indonesia. Phone/fax:+62 342 577200.
E-mail: smno@ub.ac.id
His academic experience is:
- Doctor of Philosophy (Dr.), Natural Resource and Environmental Management, Institut Pertanian Bogor (IPB), Bogor, West Java, Indonesia, 1991.
- Masters of Science (MS), Natural Resource Management, Institut Pertanian Bogor (IPB), Bogor, West Java, Indonesia, 1988.
- Bachelor of Science (Ir), Soil Science, Fac. Of Agriculture, University of Brawijaya, Malang, East Java, Indonesia, 1980.