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The Analysis of Trip Assignment of Water Trucks as Heavy Vehicles with PTV Visum

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ABSTRACT/ABSTRAK

Ketersediaan air bersih menjadi salah satu kebutuhan yang harus dipenuhi bagi kelancaran aktivitas manusia. Di Kota Kupang, sebagian masyarakat menyediakan air bersih dengan cara membeli air dari pangkalan air menggunakan sarana transportasi berupa kendaraan berat truk pengangkut air. Pengantaran air ini menggunakan ruas jalan yang dilalui oleh kendaraan lainnya sehingga kendaraan berat tersebut meningkatkan volume lalu lintas, mengurangi kecepatan dan mengurangi kapasitas jalan yang berakhir dengan meningkatnya angka kemacetan. Penelitian ini bertujuan mengetahui pemilihan rute kendaraan berat truk pengangkut air dengan menggunakan Matriks Asal Tujuan (MAT). Untuk mengetahui sebaran pergerakannya digunakan metode Model Gravity Double Constrained (DCGR) dengan fungsi hambatan eksponensial negative yang menghasilkan model distribusi Tid = Oi.Dd.Ai.Bd.exp(-0,756.Cid) dengan total distrubusi kendaraan dari zona Oebobo, Oebufu, Liliba, Oepura dan Oesapa adalah sebanyak 89 kend/hari Hasil pembebanan yang diperoleh dari PTV Visum menghasilkan lalu lintas tertinggi dari zona Oebufu ke Oesapa dengan menggunakan rute Jl. Kejora-Jl. Polisi Militer-Jl. W.J. Lalamentik.

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1. INTRODUCTION

As the needs of advanced transportation system grow, various difficulties, especially in developing countries, also increase. Therefore, the availability of trip patterns is crucial to anticipate the growing needs of infrastructure in the future (Suthanaya and Maulidia, 2019). Also, the availability of transportation modelling in order to achieve quality transportation is enhanced by the rapid grow of digitalization (Maget et al., 2019).

In order to describe the trip patterns of travelers in a study area, it is necessary to conduct an Origin-Destination Survey which is useful for making an Origin-Destination Matrix (ODM). Previous research generated an estimation of the trip distribution in West Java Province based on statistical test results using the DCGR model with a negative exponential impedance function of Tid = Oi.Dd.Ai.Bd.exp(-0.014159.Cid) (Aprilliansyah and Herman, 2015). A research in Denpasar, Bali also shows that the total distribution of predicted future trips in 2033 is of 28,873,490 people / day (Suthanaya and Maulidia, 2019).

Kupang City is the capital of East Nusa Tenggara Province, with the population growth of 3% per year (Citra et al,. 2019). The basic activities of the citizens of Kupang City is, undeniably, linked with the availability of clean water. Therefore, to meet these needs, citizens purchase clean water sold by private companies delivered

through water trucks. When delivering clean water, these heavy vehicles pass through public roads that are also used by other vehicles. This condition increases the traffic and affects the road capacity.
This study aims to determine the trip assignment taken by the water trucks using Origin-Destination Matrix (ODM). The data was obtained from a trip distribution survey starting from the location of the water collection points to the delivery points. Bencomo et al., (2018) conducted a research project in the city of El Paso, United States that provided a model for transportation planners in distributing the total number of trips.
PTV Visum utilises computerized traffic models approach which provides solutions for the development of transport network and transport demand models (including trip generation, trip attraction, and spatial trip distribution) (Jacyna et al., 2017).

1.1. Origin-Destination Matrix (ODM)

The Origin−Destination Matrix (ODM) is often utilised by transportation planners to describe trip patterns. Trip patterns in transportation systems are often depicted through trips (vehicles, passengers, and goods) flowing from origin zone to destination zone within a certain area and over a certain period.
The ODM is a two-dimensional matrix that generates the number of trips between zones within a given region. The origin zone is listed in rows and the destination zone is listed in columns, so each cell of the matrix states the number of trips from the origin zone to the destination zone. Furthermore, T_id is a notation in the matrix cell that shows the value of the trip flows, whether it is for vehicles, goods, or passengers, from the origin zone i to the destination zone d in a certain time interval. Once the ODM is loaded into the road network system, this can yield trip patterns. Therefore, studying the trip patterns can provide solutions in advance to various transportation challenges.
The ODM plays an imperative role in various transportation planning and management studies because it can provide detailed information of trip's demands. Some important elements in the ODM are number of zones and values of each cell. The number of zones indicates how many ODM cells must be generated and contains necessary information for trip planning. In addition, each cell requires information on distance, time, cost, or a combination of these three information that is used as a measure of accessibility (convenience). The general form of the ODM can be seen in Table 1.

Table 1. General Forms of The ODM

Zone	1	2	3	…	N	Oi
1	T11	T12	T13	…	T1N	O1
2	T21	T22	T23	…	T2N	O2
3	T31	T32	T33	…	T3N	O3
.	.	.	.	…	.	.
.	.	.	.	…	.	.
.	.	.	.	…	.	.
N	TN1	TN2	TN3	…	TNN	ON
Dd	D1	D2	D3	…	DN	T

1.2. Trip Distribution

Trip distribution defines the circulation of trip from one zone to several other zones known as inter-zone travel. Several methods can be used in assembling trip distribution, one of which is the Synthetic Method.
The gravity (GR) model, one of the most often used synthetic methods, is quite simple and easy to use. This model simulates the characteristics of trip generation and trip attraction that are related to several parameters of the origin zone, such as population and accessibility (convenience) in terms of distance, time, or cost. The accessibility factor is used as an impedance function computed by using the negative exponential function. Meanwhile, parameter β is obtained from the quotient between K values, ranging from 2~3, with the average of the impedance value $\overline{C_{id}}$ (Aprilliansyah and Herman, 2015).

$$f_{(cid)} = e^{-\beta(Cid)} \qquad (1)$$

The modelling is done with the Doubly Constrained Gravity (DCGR) as seen in equation (1) (Tamin, 2000).

$$T_{id} = O_i.D_d.A_i.B_d.f_{(cid)} \qquad (2)$$

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Where:

T_{id}	=	Number of trips between zones i and d (trips/day)
O_i	=	Number of trips originating from origin zone i (trips/day)
D_d	=	Number of trips originating from destination zone d (trips/day)
A_i	=	Generation balancing constant
B_d	=	Attraction balancing constant
$f_{(cid)}$	=	Impedance function

With limit conditions as seen in equation (3) and equation (4) below:

$$B_d = \frac{1}{\sum_{d=1}^{N}(A_i.O_i.f_{(cid)})} \quad (3)$$

$$A_i = \frac{1}{\sum_{d=1}^{N}(B_d.D_d.f_{(cid)})} \quad (4)$$

1.3. Trip Assignment

This particular stage is referred to as the trip assignment stage, where the traffic volumes are propagated over possible routes. At this stage, several factors are taken into consideration in order to determine the route chosen by users, such as operating and service conditions. Some of the conditions are quality, reliability, regularity, travel time, distance, cost of fuel, congestion, queues, type of manoeuvre needed, type of highway (toll roads, arteries, etc.), scenery, completeness of road signs and markings, and habits.

Users will attempt and assess the route that best suits their individual needs with the aim of minimizing travel costs, including travel time. The best route is generated after a set of trial and comparison between alternative routes for the same destination. As each user will attempt similar trial process, there is a possibility that certain routes will decrease in performance, and users will try to switch to another route that shows better performance. This occurs continuously in order to create a balance of routes loaded on the network.

It is worth noting that the travel time will always increase alongside the surge of traffic volume on a particular route. According to user equilibrium, travel time on route 1 and route 2 will intersect at a certain point where the travel time for both routes is the same. Users tend to experience route 1 and route 2 similarly so the travel time from one point to another is considered the same. Figure 2 illustrates user equilibrium, where Wardlop's first principle applies. Balance occurs on route 1 and 2 with the same travel time. Congestion is not a consideration in the selection of route 1 or 2.

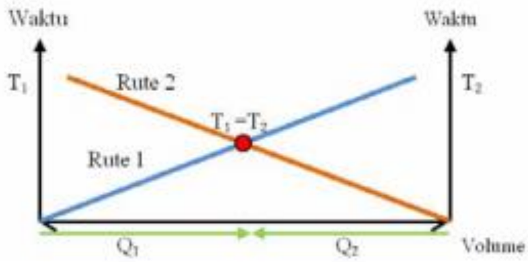

Figure 1. Volume and travel time graph in the Equilibrium Assignment model

Examples of user equilibrium loaded on to four alternative routes between point A to point B can be seen in Figure 2 and Table 2. Both illustrate the balance of trips with the same travel time. Travel time equation is a function on the trip volume of each route.

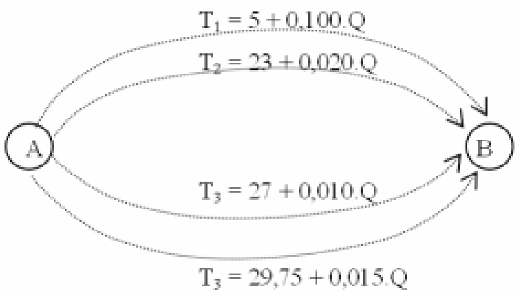

Figure 2. Example of trip assignment

Table 2. Travel Time Calculation

Route	Q (Vol)	Equation	T (time)
1	300	5+0.100.Q	35
2	600	23+0.020.Q	35
3	800	27+0.010.Q	35
4	350	29.75 + 0.015.Q	35

1.4. PTV Visum

8 PTV Visum is the world's leading software in macroscopic modelling of transportation needs and, to date, is used by more than 1000 organizations. It is part of transportation demand modelling on the traffic network,
8 with additional functions that can analyze external effects of traffic, such as air pollution and noise levels (AR, 2021).

Traffic load model can be done through PTV Visum, in which the output can be used in measuring the observed road networks. Overall, this step examines three components, namely the trip matrix, road network, and loading mechanism (including the selection of freight transportation routes and restrictions on goods vehicles on certain road sections) (Citra, 2019).

The process of distributing the trips is part of four sequential stages of transportation modelling. Trip generation and attraction are calculated through trip generation procedure by determining the impedance matrix of the
4 total trip demand. The elements of the matrix itself are calculated in the trip distribution procedure. On the one
4 hand, the allocation of the destination zone to the origin zone is based on the attraction of the trip, and on the other hand, the allocation of the origin zone to the destination zone is measured by the matrix of travel time, fares, and other general costs (Visum 15, 2015).

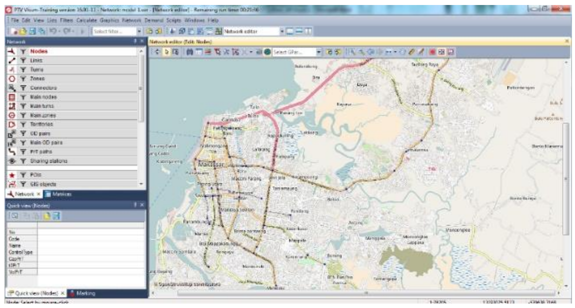

Figure 3. Observation points map in PTV Visum (AR, 2021)

2. RESEARCH METHODS

The research started with a preliminary study that had been previously conducted to identify the volume of heavy vehicles, specifically water trucks in Kupang City. Subsequently, various challenges related to the volume of water trucks that affected the road capacity were identified. Aa reference matrix is then created based on the research's topic and objectives. Afterward, direct survey was carried out through conducting observations, interviewing, and distributing survey forms at the water collection points (origin zone) and delivery points (destination zone). The survey was conducted in five working days according to the number of research location zones, namely zone 1 (Oebobo), zone 2 (Oebufu), zone 3 (Liliba), zone 4 (Oepura), and zone 5 (Oesapa).

Following this, data recapitulation and processing were performed. The data was processed, with Microsoft Excel, into the Origin-Destination Matrix (ODM) and the trip distribution was calculated with DCGR model, which were then loaded to the road network using the PTV Visum. Once the trip distribution data was obtained, then the trip assignments chosen by the water trucks were analysed. The results, therefore, can be used as a basis for traffic management policy making in the future.

2.1. Trip Distribution Survey

The trip distribution survey was carried out by collecting four types of data, namely number of heavy vehicles, travel time, travel distance, and travel time.

2.1.1. Number of Heavy Vehicles

This survey was conducted in 5 research zones: Oebobo Village, Oebufu Village, Liliba Village, Oepura Village, and Oesapa Village which can be seen in Table 3. The survey was conducted from 07.00 to 18.00 each day for five days, where each zone was observed in one day.

Table 3. Division of Trip Distribution Zones

Zone	Village
1	Oebobo
2	Oebufu
3	Liliba
4	Oepura

The survey was done by identifying and monitoring water trucks in each origin zone (water collection points) to the destination zone (delivery points). The surveyor then discussed with drivers and asked for consents to record the vehicle number and to be followed until the arrival to the destination zone.

2.1.2. Travel Time

Travel time was measured by recording the time of departure from the origin zone (water collection points) to the destination zone (delivery points) through which these water trucks passed. The survey was conducted on each zone and on each water truck using a simple timer application on a smartphone.

2.1.3. Mileage

This survey was conducted by recording the distance from the origin zone (water collection points) to the destination zone (delivery points) passed by these water trucks. The survey was conducted on each zone and on each water truck using a simple distance measuring application on a smartphone.

2.1.4. Travel Expenses

This survey was done by enquiring the driver on the estimated cost of traveling from the origin zone (water collection points) to the destination zone (delivery points) passed by water trucks. The survey was conducted on each zone and on each water truck as well.

3. RESULT AND DISCUSSION

The survey results loaded into an Origin-Destination Matrix (ODM) for five research zones can be seen in Table 4. Based on the ODM, the highest origin zone is from zone 3 (Liliba Village), with the value of 28 vehicles/day. Zone 2 (Oebufu Village) is the second highest origin zone with the value of 23 vehicles/day. Meanwhile, zone 5 (Oesapa Village) is the third highest origin zone with the value of 16 vehicles/day.

Furthermore, the highest destination zone is in zone 3 (Liliba Village), with the value of 28 vehicles/day. The second highest destination zone is in zone 5 (Oesapa Village), with the value of 17 vehicles/day. Zone 2 (Oebufu Village) is the third highest destination zone, with the value of 16 vehicles/day. The origin zone with the lowest trip distribution is in zone 4 (Oepura Village), with the value of 16 vehicles/day. Also, the lowest destination zone is in zone 4 (Oepura Village), with the value of 13 vehicles/day.

Moreover, the number of trips from the origin zone to the highest destination zone is 20 vehicles/day, which is shown in the Liliba Village. Meanwhile, the lowest trip distribution from the origin zone to the lowest destination zone, with a value of 1 vehicle/day, is shown within the Oebobo Village zone, within the Oepura Village zone, between Oebufu Village and Oepura Village, between Oepura, Liliba and Oesapa Villages, and between Oesapa, Oebobo and Liliba Villages.

Table 4. The Result of Origin-Destination Matrix (ODM) of Water Trucks

Zone	1	2	3	4	5	Oi
1	1	2	2	5	2	12
2	7	3	4	1	8	23
3	2	2	20	2	2	28
4	4	3	1	1	1	10
5	1	6	1	4	4	16
Dd	15	16	28	13	17	89

This shows that Liliba Village has a high trip distribution. Liliba Village has an abundant level of land water resource and has adequate accessibility. These conditions have generated a high number of demands of clean water within the zone and between other zones.

3.1. Impedance Function Analysis

Furthermore, based on the trip distribution results, distance, as part of accessibility factors, is chosen as an impedance function for the Origin-Destination Matrix (ODM) calculation. Distance provides an overview of 2 the shortest and longest route in the trips from the origin zone to the destination zone. Table 5 illustrates that the shortest distance is obtained from zone 3 (Liliba Village) to zone 5 (Oesapa Village) with the route from Bumi 1 Street to Piet A Tallo Street. The distance between these zones is relatively short, and the road access is decent. Meanwhile, the longest route is shown between zone 4 (Oepura Village) to zone 5 (Oesapa Village) with the route from Anggrek Street to Suharto Street and to El Tari Street. The distance between these two villages is quite long, thus the accessibility matrix shows a high number.

Table 5. Accessibility Matrix (C_{id})

Zone	1	2	3	4	5
1	1,30	3,70	3,30	1,09	2,09
2	2,82	2,33	2,61	1,52	2,25
3	3,15	2,60	1,50	2,00	0,98
4	3,38	2,37	4,40	2,80	4,80
5	4,50	3,82	1,50	2,20	2,35

The value of the impedance function of each origin-destination zone using a negative exponential function with 3 a $(\overline{C_{id}})$ value of 2.645 and a β value of 0.7560 can be seen in Table 6.

Table 6. Accessibility Function Matrix ($f_{(cid)}$)

Zone	1	2	3	4	5
1	0,3743	0,0610	0,0825	0,4387	0,1116
2	0,1189	0,1722	0,1393	0,3169	0,1832
3	0,0924	0,1401	0,3225	0,2205	0,4785
4	0,0780	0,1671	0,0359	0,1204	0,0265
5	0,0333	0,0558	0,3217	0,1895	0,1692

3.2. DCGR Model Analysis

20 The result of Origin-Destination Matrix (ODM) is then analyzed with the DCGR model by entering the distance value, as an impedance function, that has been previously calculated. Subsequently, the data is processed with the A_i and B_d values for each origin and destination zone. The reiteration process begins by assuming the values of B_1, B_2, B_3, B_1, and B_4 = 1 and is repeated 14 times until each A_i and B_d value reaches convergence or static mode, despite any subsequent recurrences.

2 Afterward, the results are loaded into the Origin-Destination Matrix (ODM) using the equation (2). The result of trip distribution of water trucks by distance factor with DCGR model is presented in Table 7.

3 The results show that there is a difference between the result of Origin-Destination Matrix (ODM)) with 3 original measurement and the result of Origin-Destination Matrix (ODM) with the DCGR model. As seen, there is a significant change between origin zone 5 (Oesapa Village) and the destination zone 3 (Liliba Village) where the initial value of 1 vehicle/day changes to 9 vehicles/day, through the route from Timor Raya Street to Bunda Hati Kudus Street to Piet A. Tallo Street. The distance between Oesapa Village and Liliba Village is quite short, and the trip distribution is more concentrated.

After being modelled, Zone 3 (Liliba Village) also experiences changes in trip distribution. There is a significant reduction for Liliba Village as the destination zone or within the Liliba Village zone itself, which

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falls from 20 vehicle/day to 11 vehicles/day through the route of Bumi Street to Lakbanu Street. This process aims to provide a more even trip distribution for the surrounding zones.

Table 7. Origin-Destination Matrix (ODM) With the DCGR Model

Zone	1	2	3	4	5	oi	Oi	Ai	Ei
1	6	1	2	3	1	12	12	0,0572	1,00
2	4	5	5	4	4	23	23	0,0637	1,00
3	3	4	11	3	9	28	28	0,0439	1,00
4	2	5	1	1	1	10	10	0,1283	1,00
5	1	1	9	2	3	16	16	0,0677	1,00
Dd	15	16	28	13	17	**89**			
Dd	15	16	28	13	17		**89**		
Bd	1,4689	1,3487	0,9504	0,7161	0,8687				
Ed	1,00	1,00	1,00	1,00	1,00				1,00

Furthermore, zone 3 (Liliba Village) and zone 4 (Oesapa Village) also see changes in trip distribution, specifically from Bumi Street to Piet A Tallo Street. Similar to the previously explained change between zone 5 and zone 3, there is an increase in trip distribution from 2 vehicles/day to 9 vehicles/day. So, it can be concluded that the trip distribution between zones needs to be increased.

In order to make the trips more even, while still taking into account the distance, there is a modification in the inter-zone trip distribution value, such as in zone 1 (Oebobo Village) where there is a change of an initial value of 1 vehicle/day to 6 vehicles/day with the route from W. Monginsidi III Street to Shopping Center Street.

In zone 4 (Oepura Village), the change occurs towards the destination zone 1 (Oebobo Village). There is a decrease from 4 vehicles/day to 2 vehicles/day from Anggrek Street to Suharto Street and to El Tari Street. These zones are located quite far away from each other and, in consequence, are experiencing a decrease trip distribution. Conversely, in the destination zone of Oebufu Village, there is an increase from 3 vehicles/day to 5 vehicles/day within the route of Anggrek Street to Kejora Street, due to the short distance between these two zones. The model, thenceforth, recommends an increase of trips distribution.

The comparison of the Origin-Destination Matrix (ODM) with original measurement and the Origin-Destination Matrix (ODM) with DCGR model can be seen in Figure 4. The result of the comparison of these two matrices produces the equation of Y = 2.426 + 0.318X with the value of the correlation coefficient (r) = 0.5. This shows that both matrices show a fairly close correlation.

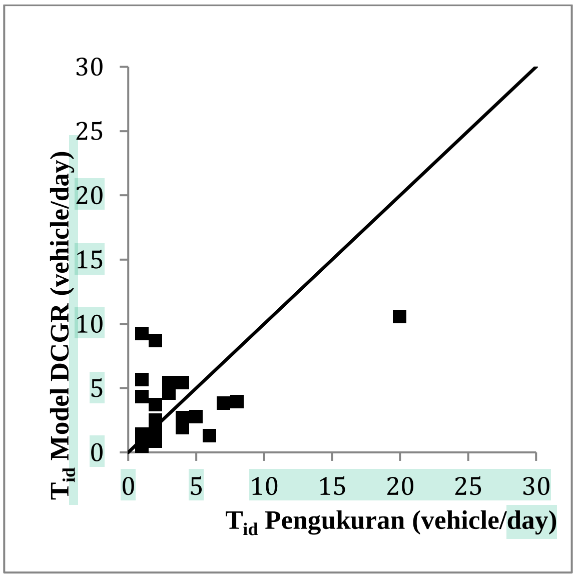

Figure 4. Comparison of ODM with initial measurement with ODM with DCGR model

3.3. Loading with PTV Visum

Following the previous described step, the result of Origin-Destination Matrix (ODM) with the DCGR model is then loaded to the road network using the PTV Visum application. Several data then are loaded into the application, such as zone data (in form of nodes, links, zones and connectors), the data from the Origin-

Destination Matrix (ODM) with the DCGR model, traffic characteristics (such as the initial road capacity and initial speed obtained from secondary data resources), and travel time obtained from survey.

Figure 5. Trip distribution generated from PTV Visum Application

The Origin-Destination Matrix (ODM) is calculated using the Equilibrium Assignment method. Figure 5 illustrates the trip distribution¬ from the origin zone to the destination zone of water trucks.
In addition to trip distribution, the PTV Visum application also generates information on vehicle volume for each link or road that connects the origin zone and destination zone. Based on Table 8, the highest trip distribution is from the origin zone 2 (Oebufu Village) to the destination zone 5 (Oesapa Village), with the value of 9 vehicles/day from Kejora Street to Polisi Militer Street and to W. J. Lalamentik Street. Meanwhile, the lowest volume, with a value of 0 vehicle/day, is seen between the origin zone 1 (Oebobo Village) and the destination zone 2 (Oebufu Village), specifically from Frans Seda Street to W.J. Lalamentik Street, and between zone 4 (Oepura Village) and zone 5 (Oesapa Village), specifically on Anggrek Street to Suharto Street and to El Tari Street. There are differences of trip distribution between the initial measurement and the DCGR model. Although the changes are not significant, it is still necessary to pay a close attention to the factors that create the change, such as road conditions and the surrounding environment.

Table 8. Vehicle Volume of Each Origin Zone and Destination Zone Based on PTV Visum

Origin Zone	Destination Zone	Volume (vehicle/day)
1	2	0
2	1	7
1	3	2
3	1	2
1	4	7
4	1	4
1	5	2
5	1	1
2	3	4
3	2	2
2	4	1
4	2	6
2	5	9
5	2	6
3	4	2
4	3	1
3	5	2
5	3	1
4	5	0
5	4	4

4. CONCLUSSION

In the Kupang city, citizens purchase clean water sold by private companies delivered through water trucks. When delivering clean water, these heavy vehicles pass through public roads that are also used by other vehicles. This condition increases the traffic and affects the road capacity. Object of the research is water truck and used DCGR Model as methode. sThe total distribution of water trucks produced by each zone is 89

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vehicles/day. The calculation of Origin-Destination Matrix (ODM) with the DCGR model shows a travel distribution model of $Tid = Oi.Dd.Ai.Bd.\exp(^{(-0.7560.Cid})$. Moreover, based on the trip distribution prediction results, the highest trip distribution occurs between Oepura Village and Oesapa Village, with the value of 9 vehicles/day on the route of Kejora Street to Polisi Militer Street and to W.J. Lalamentik Street. To conclude, in order to anticipate a high volume of heavy vehicles passing through certain roads, alternative solutions generated through traffic modelling and engineering are critically necessary..

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