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ВЛИЯНИЕ ВРЕМЕНИ ОЖИДАНИЯ В ОЧЕРЕДИ НА ВРЕМЯ ДОСТАВКИ

THE EFFECT OF QUEUE ON DELIVERY TIME

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Аннотация. *Планирование маршрута - сложная проблема в сфере перевозок и поэтому необходимо учитывать несколько факторов, начиная с вместимости транспортного средства и потребительского спроса, распределения водителей для перевозки, расстояния, времени в пути. Транспортировка, как один из ключевых элементов логистики и две трети логистических затрат, нуждается в дальнейшем изучении. В этой статье изучалось влияние ожидания в очереди на время в пути, которое могло произойти в магазине покупателя. В этом исследовании были собраны соответствующие данные, которые включали три грузовика, двадцать четыре координаты покупателей-детских магазинов, вместимость грузовиков и объем товаров. Связанными теориями были задача множественного коммивояжера и теория массового обслуживания – один сервер и использование дисциплины FIFO – первый вход, первый выход (M/M/1), а также экспоненциально распределенная случайная величина. Маршрут начался с главного склада в 08:30 из Тангеранга, заказы были отправлены клиентам, расположенным в Джакарте, обеденный перерыв с 12:00 до 13:00 и возвращение на главный склад до 17:30 с обычной скоростью. OptimoRoute, как одно из подходящих программ для решения проблемы маршрутизации транспортных средств, использовалась для определения последовательности отправки, распределения заказов для водителей и необходимого времени. Онлайн-симулятор использовался для устранения эффекта очереди. Результаты показали, что время в пути на каждую остановку увеличивалось примерно на пятнадцать минут; чем больше магазинов, тем больше времени требовалось. Это дополнительное время может повлиять на стоимость сверхурочных, если время в пути превышает рабочие время. Планировщик должен учитывать время ожидания в очереди при планировании следующего маршрута.*

Ключевые слова: *планирование маршрута, ожидание в очереди, время в пути.*

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Abstract. *Route planning is a complex problem in transportation, and one has to consider several factors starting from vehicle's capacity and customer's demand, allocation of drivers for shipment, distance, travel time. Transportation as a one of the key elements in logistics and two third logistics costs, needs study further. This paper studied the effect of queuing activity on travel time that could be happened at customer's shop. This study collected the related data which were three trucks, twenty-four coordinates of customers-baby shops, capacities of trucks, and volume of goods. The related theories were multiple traveling salesman problem (mTSP) and queuing theory – single server and using the FIFO – First In First Out discipline (M/M/1), and exponential distributed random variable. The route started from the main warehouse at 08:30 from Tangerang, shipped the orders to the customers located in Jakarta,, lunch break 12:00 to 13:00 and return to the main warehouse before 17:30 by using normal speed. OptimoRoute as one of the suitable software for solving the vehicle routing problem was used to solve the sequence of shipment, order allocation for drivers and time needed; where On Line Simulator was used to solve the effect of queue. The results indicated that there was an additional time around fifteen minutes per stop to travel time; the more shops, the longer time was needed. This additional time may impact the overtime cost if the amount of travel time exceeds the working hour and queuing time must be considered for the next route planning by the planner.*

Keywords: *route planning, queuing activity, travel time.*

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1. Introduction

It is essential to offer products and services to consumers at the desired time and place and to deliver them on time [1]. When delivering goods or services, time becomes a critical issue for driver, in this paper we call time as a travel time. The sensitivity to travel time is usually referred to value of time. There are some factors that affect travel time, such as length or distance, congestion such as parking of vehicles along the route, delay such as number of stops, number of signalized inter-section, accident, and environment such as route direction [2,3]. Distance relates to velocity and time, when distance become farther then time needed to travel become longer. Congestion is a condition that arises because more people wish to travel at a given time than the transportation system can accommodate: a simple case of demand exceeding supply [4] and congestion makes vehicle run slower and take more time than normal to arrive at customer's destination and congestion can be avoided by choosing another route. The route choice problem can be stated as follows. Given a transportation network composed of nodes, links, origins and destinations; and given an origin, a destination and a transportation mode, what is the chosen route between origin and destination on mode [5]. Transportation is a key element of logistics, and it occupies around one third to two third of logistics cost [6], then it is important to minimize the cost of transport. Delay also affects delivery time, and queue happens when many trucks are waiting for unloaded by customer. This waiting line depends on number of trucks and goods that are ready to be unloaded. Trucks that wait for unloaded cannot be predicted by driver, and this queue makes travel time longer than normal. When supplier's driver delivers goods to customer or baby shop, he often finds that he is not the only supplier who delivers goods at the time, then, he has to wait in line until all suppliers that come before him have been finished. From this reality, planning route should consider not only travel time from starting point to destination's point, but also the amount of time that spent in a customer's place especially queue.

In this paper, the objective of research is to know how big the effect of queue for unloading process on travel time from Tangerang to Jakarta – capital city during office hours. This result will help transportation planner allocating the right amount of customer's point to driver.

2. Methods and materials

2.1. Multiple Traveling Salesman Problem

The multiple traveling salesman problem (mTSP) is a generalization of the well-known traveling salesman problem (TSP), where more

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than one salesman is allowed to be used in the solution [7]. The characteristics of the mTSP seem more appropriate for real-life applications, such as robotics, transportation and delivery, networking, disaster management, precision agriculture, search and rescue [8], order picking [9]. Mathematical model for mTSP is as follows:

The m-TSP is defined on a graph $G = (V, A)$, where V is the set of vertices or nodes and A is the set of arcs or edges. Let $C = (c_{ij})$ be the cost or distance matrix defined on the set of A. The matrix C is said to be symmetric when $(c_{ij})=(c_{ji})$, $\forall(i, j) \in A$ and otherwise is said to be asymmetric. If the cost matrix satisfies $c_{ij} \le c_{ik} + c_{kj}$ for $\forall_{i,j,k}$ then the matrix C satisfies the triangle inequality. There are various models have been proposed for the m-TSP in the literature, but assignment based mathematical model, tree based mathematical model and a three-index flow-based model have been widely used. The three-index flow-based model for the m-TSP is as follows:

Let n be the number of cities or pick locations, and m be the number of salesmen or pickers (we assume $n \ge 3m+1$), then the variable x_{ij} is defined as follows [10]:

$$x_{ij} = \begin{cases} 1, \text{ if edge (i,j) is used in the tour} \\ 0, \text{otherwise} \end{cases}$$

Goal Function: Minimize:

$$\sum_{(i,j)\in A} c_{ij} x_{ij} \qquad (1)$$

Constraints:

$$\sum_{j=2}^{n} x_{1j} = m \qquad (2)$$

$$\sum_{j=2}^{n} x_{j1} = m \qquad (3)$$

$$\sum_{i=1}^{n} x_{ij} = 1, j = 2, \dots n \qquad (4)$$

$$\sum_{j=1}^{n} x_{ij} = 1, j = 2, \dots n \qquad (5)$$

$$\sum_{i\in S}\sum_{j\in S} x_{ij} \le |S| - 1, \forall S \subseteq V - 1, S \neq 0 \qquad (6)$$

$$x_{ij} = 0 \vee 1, (i,j) \in A \qquad (7)$$

In this research, there were 3 trucks that shipped goods everyday from warehouse where located in Jatiuwung, Tangerang to 24 baby shops then returned to warehouse.

2.2. Waiting Line – Queue

Waiting line is also called queue and is where customers wait before being served [11] and become part of our daily activities such as paying for goods in department store, buying a movie ticket, ordering food in a restaurant, emergency room at the hospital and so on. Waiting causes inefficiency, for example when delaying service jobs exceeded their due dates may result in lost future business, waiting for unloading goods, administration and checking process from truck to floor may disrupt delivery for next customer. Queues arise when the short-term demand exceeds the capacity.

The components of queuing systems are arrival process, service and departure process, queuing discipline, system capacity, number of servers, and population size [12]. In this research, service discipline is FIFO because unloading process is based on which vehicle comes first and only one server at the baby shop, then when server serves and checks the goods for one supplier, he cannot serve another supplier.

Common used formulas are as follows:

$$L = \lambda W \qquad (8)$$

$$L_q = \lambda W_q \qquad (9)$$

$$W = W_q + \frac{1}{\mu} \qquad (10)$$

$$L = \lambda \left(W_q + \frac{1}{\mu}\right) \qquad (11)$$

$$\rho = \frac{\lambda}{\mu} \qquad (12)$$

where L - expected number of customers in the system, including those being served; L_q - expected number of customers in the queue; W - expected waiting time in the system, including service time for individual customer; W_q - expected waiting time in the queue; λ - mean arrival rate for customers coming to the queueing systems or expected number of arrivals per unit time; μ mean service rate or expected number of service completions per unit time; $1/\lambda$ - expected interarrival time or the average time be-

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tween the arrival of consecutive customers; 1/μ - expected service time for each customer.

2.3. Transportation and Queuing Software

2.3.1. Transportation software

In this research, OptimoRoute software was used to solve the multiple traveling salesman problem. OptimoRoute was regarded as one of the suitable software for solving vehicle routing problem and had following advantages: high ease of use, the clarity with which solutions are shown, both graphically and analytically, through the use of colors and the sense of the streets, and the high amount of data from the different routes illustrated in the solutions. There were also some disadvantages: free-30 day-trial, if the destination points are very close to each other, the graphical interpretation becomes confusing [13]. OptimoRoute is a routing optimization software, created in 2012 in the United States, used by multiple companies from different business sectors around the world. The program was at www.optimoroute.com [14].

2.3.2. Queuing software

Queuing on-line simulator was used to calculate the results of research data. This simulator was created by Associate Professor Jaroslav Sklenar, Department of Statistics and Operations Research, University of Malta and its software can be found at www.staff.um.edu.mt/jskl1/simweb/simdown.html [15].

2.4. Methods

The study was conducted at textile company which its warehouse located in Tangerang and categorized as a small and medium enterprise (SME). The product is baby and children's clothing, and its orders were from baby shops. There were three trucks and twenty-four coordinates of customers-baby shops. The capacity of first truck was nine cubic meter, second truck was eight cubic meter, and the third truck was four cubic meter. The working hours started from 08:30 a.m to 17:30 pm and break hours were from 12:00 to 13:00. The driver started the shipment was from warehouse and must be back to warehouse. Before running the optimoroute, there were some data must be collected: coordinates of twenty-four baby-shops, capacity of truck, volume of goods, the average time for unloading goods at the baby shops was 30 minutes, but not included waiting time: administration process such as receipt document and checking. Unloading process was in the large space.

The results from optimoroute was analyzed further by queuing simulator in order to get the effect of waiting time at the baby shop. Queuing discipline was first-in first-out (FIFO) and the server is one.

We assume that congestion can be avoided by using alternative route which is directed by Google maps and there is no restricted route.

3. Results and discussions

3.1. Results

3.1.1. OptimoRoute software

In figure 1, the output from optimoroute were locations, route, total time: break, travel, duration of unloading at baby shop, and total distance starting from warehouse and back to warehouse again.

Table 1 showed more detailed data, included coordinates of baby shop, order ID, stop duration and break, but unfortunately, the delivery does not always have a zero queue or waiting line at baby shop, that is why one has to consider queues by simulate various possibilities from zero to maximum customers that ever happened.

3.1.2. Queuing software

For the past six months observation, there were four customers per hour on the average (mean arrival rate, λ), and mean service rate was eight customers per hour (μ), the amount of server was 1, then when the service man was busy, the other customers must wait, the queue discipline was FIFO – First In First Out. The queueing model was M/M/1.

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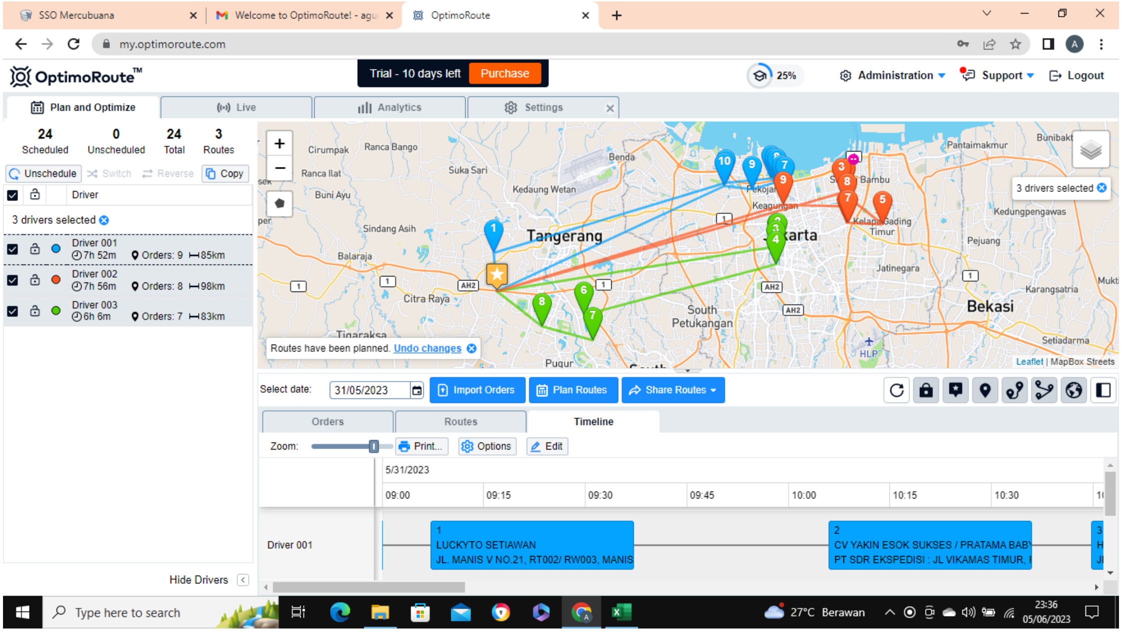

Fig.1. Output for normal speed

Table 1

Ouput data from optimoroute

Order ID	Vehicle	Stop No.	Latitude	Longitude	Unloading duration (mnt)	Break time	Depot to depot (KM)	Total time (incl. stop duration and break)
ORD020	001	1	-6.1903	106.5789	30			
ORD010	001	2	-6.1316	106.7735	30			
ORD013	001	3	-6.1284	106.8112	30			
ORD003	001	4	-6.1303	106.8139	30			
	001		-6.1303	106.8139	60	yes	85	7 hours 52 minutes
ORD009	001	5	-6.1367	106.8198	60			
ORD005	001	6	-6.1379	106.8231	30			
ORD021	001	7	-6.1307	106.8162	30			
ORD012	001	8	-6.1370	106.7953	30			
ORD014	001	9	-6.1346	106.7718	30			
ORD015	002	1	-6.1394	106.8733	45			
ORD016	002	2	-6.1394	106.8733	60			
ORD007	002	3	-6.1389	106.8699	30			
	002		-6.1389	106.8699	60	yes		
ORD008	002	4	-6.1664	106.9046	45		98	7 hours 56 minutes
ORD022	002	5	-6.1654	106.8742	30			
ORD002	002	6	-6.1652	106.8754	30			
ORD006	002	7	-6.1516	106.8751	30			
ORD018	002	8	-6.1498	106.8213	30			
ORD001	003	1	-6.1850	106.8158	30			
ORD023	003	2	-6.1847	106.8169	30			
ORD024	003	3	-6.1913	106.8154	30			
ORD004	003	4	-6.1998	106.8153	30		83	6 hours 36 minutes
	003		-6.1998	106.8153	60	yes		
ORD017	003	5	-6.2423	106.6543	30			
ORD011	003	6	-6.2633	106.6622	30			
ORD019	003	7	-6.2521	106.6199	30			

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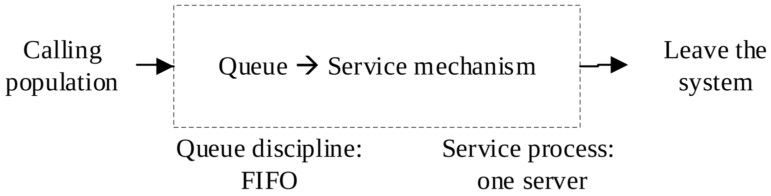
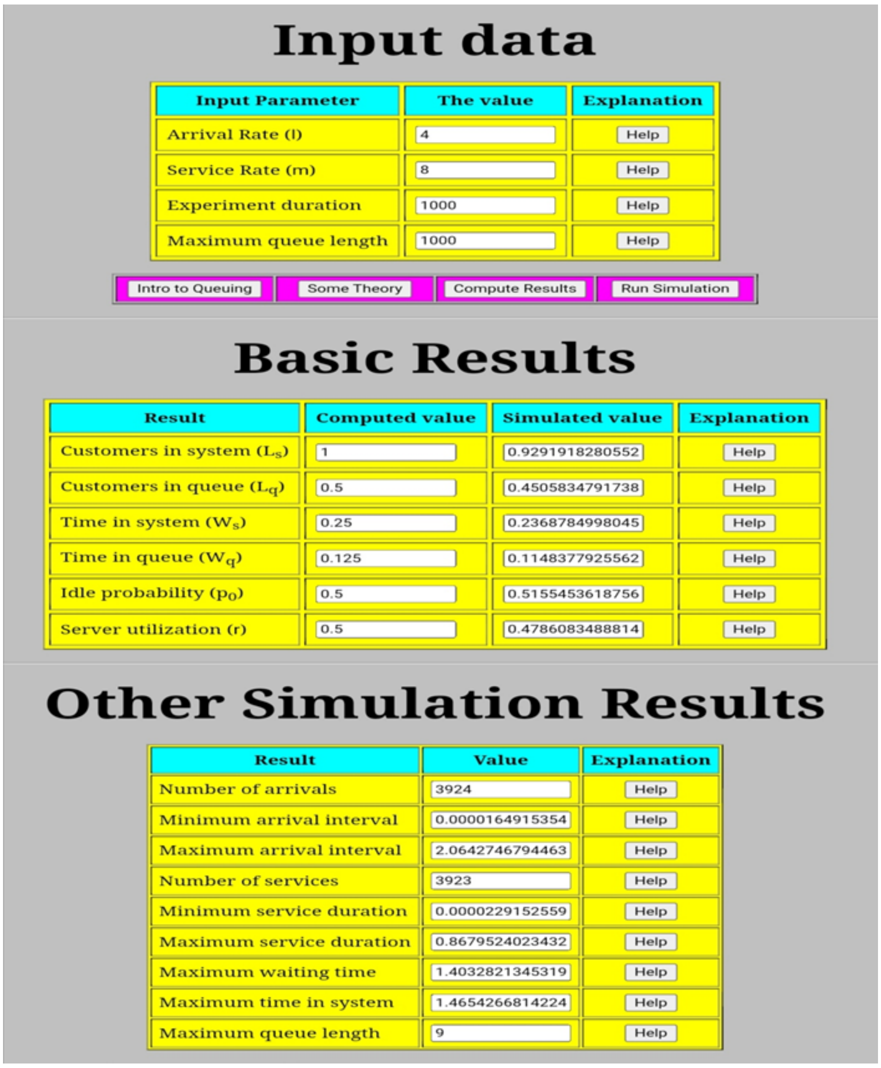


Fig.2. Queueing system



Input data

Input Parameter	The value	Explanation
Arrival Rate (l)	4	Help
Service Rate (m)	8	Help
Experiment duration	1000	Help
Maximum queue length	1000	Help

Intro to Queuing | Some Theory | Compute Results | Run Simulation

Basic Results

Result	Computed value	Simulated value	Explanation
Customers in system (L_s)	1	0.9291918280552	Help
Customers in queue (L_q)	0.5	0.4505834791738	Help
Time in system (W_s)	0.25	0.2368784998045	Help
Time in queue (W_q)	0.125	0.1148377925562	Help
Idle probability (p_0)	0.5	0.5155453618756	Help
Server utilization (r)	0.5	0.4786083488814	Help

Other Simulation Results

Result	Value	Explanation
Number of arrivals	3924	Help
Minimum arrival interval	0.0000164915354	Help
Maximum arrival interval	2.0642746794463	Help
Number of services	3923	Help
Minimum service duration	0.0000229152559	Help
Maximum service duration	0.8679524023432	Help
Maximum waiting time	1.4032821345319	Help
Maximum time in system	1.4654266814224	Help
Maximum queue length	9	Help

Fig 3. Results from On-Line simulator

The On-Line Simulator software provided two kinds of output, the first one was computed value and another one was simulated value. Mean arrival rate, $\lambda = 4$ customers per hour and mean service rate, $\mu = 8$ customers per hour are independent and exponential distributed random variable, figure 2 showed the results of computed value and simulated value.

From the above figure, there would be an additional time around 0.25 hours = 15 minutes in systems from queue when the one delivered goods to the one baby shop. This additional queue time would produce an additional of total time in delivery. The increment of queue time was greatly related to the number of customers, in this case baby shops. If the number of baby shops increases then queue time increases. The Table 2 shows summary of additional time.

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Table 2

The effect of queuing time to total time

Vehicle	Total customers	Unloading time (hours)	Travel time (hours)	Total time (hours)	Queuing time (additional hours)	Total time incl. queue (hours)	% increase
001	9	6	1.87	7.87	2.25	10.12	9.12
002	8	6	1.93	7.93	2	9.93	8.93
003	7	4.5	2.10	6.6	1.75	8.35	7.35

Planner has to plan the route carefully, because queue time will affect maximum working hours – eight hours per day. If working hours exceed eight hours, then overtime will happen.

3.2. Discussion

Some activities can be predicted how long it will take such as unloading goods, waiting in the line and distance, but some factors are difficult to predict such as congestion, accidents. Congestion can be anticipated by checking Google maps, accidents can be anticipated by driving slower for crowded traffic.

4. Conclusions

Planning route based on distance only is not enough. Planner needs to consider queuing activities that happen at the customer's location for delivery services. By combining two methods, mTSP – OptimoRoute software and queuing theory – On Line Simulator, there was an additional time around fifteen minutes per customer's point, the more customer's point, the more time was needed. This additional time was linear to the number of customer's point.

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