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AUCTION BASED DISPATCH MODEL IN ONLINE MOTORCYCLE TAXI SYSTEM

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ABSTRACT

One problem in the existing online motorcycle taxi system is generalization among drivers. The generalization includes price, travel distance, and pickup distance. Meanwhile, both drivers and passengers cannot be generalized. For example, some drivers want to get higher price while other drivers want to take shorter travel distance. In the other side, some passengers want to get lower price while other passengers want to get lower waiting time. Based on these needs, in this research, we propose new online motorcycle taxi dispatch system that accommodates this various requirements. The proposed model is developed based on auction model. The auction is done automatically, sealed, and it is single round auction. In this research, the driver's requirements are: maximum travel distance, maximum pickup distance, and price range. Meanwhile, the passenger's requirements are: maximum waiting time and price range. There are three proposed models in this research. In the first model, pickup distance limitation is implemented. In the second model, travel distance limitation is implemented. In the third model, both pickup distance and travel distance limitations are implemented. In the test, besides comparing to each other, these proposed models are also compared with the previous nearest driver model. The test result is as follows. The previous nearest driver model performs the highest success ratio. The first model performs the highest average driver revenue. The third model performs the lowest average waiting time and average pickup distance.

Keywords: *Dispatch system, Online motorcycle taxi, Auction, Nearest driver, Multi agent.*

1. INTRODUCTION

Nowadays, online motorcycle taxi business grows very fast, especially in Indonesia. At the beginning, there are many online motorcycle taxi providers. Now, the competition is just two horses race between Go-Jek with its Go-Ride and Grab with its Grab-Bike [1,2]. Go-Jek is local company while Grab is Malaysian based company. Before this, Uber is in the competition. After the very hard competition, Uber decided to sell its business in south-east Asia to Grab [1]. This action is caused by the fierce competition in ride hailing industry, especially in Indonesia [3,4]. The business that is sold to Grab includes the raid hailing and food delivery [4]. This fierce competition that is faced by Uber makes the company's lost at $4.5 billion in 2017 [4]. So, by consolidating business, it hopes the company will make profit as soon as possible [4].

Even the growth is very fast and the public acceptance is very high, the business model in online taxi is still far from stable. The system, such as the dispatch system, reward system, and compensation system are still improved continuously. But, there is big difference between these two providers. Go-Jek adopts multi agent dispatch model which the driver can accept or reject the order [5]. This agent based model has been simulated in our previous work to measure its performance [5]. Meanwhile, Grab adopts mandatory dispatch model which the driver must accept all orders. This mandatory model is also has been simulated in our previous model that uses nearest driver model to measure its performance [6].

The problem in the both existing models is that these models tend to generalize both the driver and the passenger [5,6]. Especially in the nearest driver method, the order will be allocated to the nearest available driver [6]. The purpose is by allocating the order to the nearest driver, passenger's waiting time and driver's pickup distance will be the lowest [7]. It is because in many researches, one of taxi passenger interest is in reducing waiting time [7]. Meanwhile, one of taxi driver interest is reducing pickup distance because in taxi business model, pickup cost is not charged to the passenger and this cost reduces driver's revenue [8].

Unfortunately, both passenger and driver interest cannot be simplified as it is covered in the existing online motorcycle dispatch model [5,6]. After large number of conversations with the drivers and passengers, some intentions have not been covered in the existing system. Some drivers want to take shorter travel distance order while others are tolerant to take longer one. Some drivers want to take shorter pickup distance order while others are tolerant to take longer one. Some drivers want to take higher travel price while others are tolerant to lower one.

This condition also occurs in passenger side. Some passengers want to get lower waiting time while others are tolerant to longer one. Some passengers want to get lower travel price while others are tolerant to higher one. That is why some passengers, for empathy reason, give some tip to driver.

Based on this condition, the motivation and the justification of this research are proposing and to developing new dispatch model that accommodates those mentioned interests. This model also treats both driver and passenger as a personal and not just as a common entity [6]. Auction based approach is proposed in this research because many existing researches in taxi dispatch model used nearest driver approach [7,14,15], FIFO approach [16,17], or agent based approach [5].

Based on the existing condition and the research motivation, the main research question is how this new model is developed or in what basis the model will be developed. The following question is how better the proposed model solve this problem comparing to the existing dispatch model.

So, the research purpose is to develop the new online motorcycle taxi dispatch model that accommodate these driver and passenger needs. The proposed model then will be compared with the existing model, especially nearest driver model [6]. The comparison is needed to measure how better the proposed model compared with the existing model.

The hypothesis of this research is this auction based dispatch model is better than the previous nearest driver dispatch model. To prove this hypothesis, this proposed auction based model then will be compared to the nearest driver based model both for driver and passenger interests. The parameters that are evaluated includes: success ratio, revenue, pickup distance, and waiting time.

In this research, the proposed model is developed by combining auction system with multi agent system. The auction system is used because as part of negotiation system, the purpose of the system is finding best solution among parties. Meanwhile, multi agent system is used because this system is broadly used in model that treats entities inside the system as autonomous objects.

Based on the research purpose and method that is used for the basis, contributions of this research are as follows. First, this research proposes personalization approach rather generalization approach as it is used in many taxi dispatch model. Second, this research also includes price range in dispatch process rather than common parameters, such as: pickup distance, waiting time, and idle time. Third, this research enriches the implementation of computational based auction, especially for taxi dispatch process.

Basically, this research position is the combination between IT research and computing research, but, the IT portion is more dominant rather than the computing research. In IT area, this research is the part of the online motorcycle taxi system so that the system integrates the three entities: passenger, driver, and online motorcycle taxi company. In the entire online motorcycle taxi system, this model can be used in the dispatch part. Meanwhile, there is cross section with the computing area because there is effort to develop auction model automatically.

The paper is organized as follows. In the first section, we describe the background, research motivation, research question, research purpose, and the paper organization. In the second section, we explain the existing online motorcycle taxi dispatch system. In the third section, we explain the basic concept of the negotiation and auction. In the fourth section, we explain the proposed model. In the fifth section, we explain the implementation of the model into the simulation application. In the sixth section, we explain the the tests, the result analyzes, and the research finding. In the seventh section, we make conclusion and propose future research potentials.

2. EXISTING ONLINE MOTORCYCLE SYSTEM

In this section, we explain the condition in existing online motorcycle taxi system. In this system, we will show the mandatory based system that is shown in our previous work [6]. There are two methods: the nearest driver model and longest driver model. In the nearest driver model, the order will be dispatched into the driver whose location is the nearest to the pickup location [6]. The purpose of this model is to minimize the passenger's waiting time and the driver's pickup distance. The second model is the longest idle time. In this model, the order will be allocated to the driver within the observation range whose idle time is the longest one [6]. The purpose of this model is to prioritize the driver who has waited order for the longest time. The observation range is used to keep the passenger's waiting time and driver's pickup distance still low.

The illustration is as follows. Suppose that there are 10 drivers around the passenger who makes pickup orders. The driver's parameters are distance between passenger and driver (d_{pas}) and driver's idle time (t_{idle}). The observation range is set 3 kilometers. The detail information is shown in Table 1.

Table 1. Driver's Current Parameter

Driver	d_{pas} (km)	t_{idle} (second)
m_1	2.5	150
m_2	3.6	180
m_3	4.1	48
m_4	5.5	200
m_5	0.8	130
m_6	1.3	60
m_7	0.2	30
m_8	0.4	45
m_9	2.2	60
m_{10}	1.6	70

Based on data in Table 1, when the nearest driver model is implemented, then the system will allocate the order to driver m_7. It is because the distance between the passenger pickup location to the driver m_7 location is the nearest among other drivers. The problem, the idle time of driver m_7 is the lowest one among other drivers. So, from queuing point of view, the nearest driver model is not so fair.

Meanwhile, when the dispatch system adopts longest idle time model [6], the scenario is as follows. When the observation range is 1 kilometer, the order will be allocated to driver m_5. When the observation range is 2 kilometers, the order is still allocated to driver m_5. When the observation range is 3 kilometers then the order will be allocated to driver m_1. When the observation range is 4 kilometers, the order will be allocated to driver m_2. When the observation range is 5 kilometers, the order is still allocated to driver m_2. If it is assumed that the driver's speed is 2 kilometer per minute, then the maximum passenger's waiting time from observation range 1 kilometer to 5 kilometers is 2 minutes, 4 minutes, 6 minutes, 8 minutes, and 10 minutes consecutively.

The problem is there are conditions that are still uncovered by the existing system [5,6]. The first problem is the driver's maximum pickup distance ($d_{maxpick}$) and maximum travel distance ($d_{maxtrav}$). Some driver tends to get orders from shorter pickup distance or travel distance. Other drivers are tolerant for further pickup distance or travel distance. The example of driver maximum pickup distance and maximum travel distance parameters is shown in Table 2.

Table 2. Driver's Distance Parameter

Driver	$d_{maxpick}$ (km)	$d_{maxtrav}$ (km)
m_1	3	8.5
m_2	2	10
m_3	2	15
m_4	1.5	15
m_5	1	5
m_6	0.5	5
m_7	0.5	6
m_8	1.5	8
m_9	1.1	10
m_{10}	2.5	12

Now, there are two passengers named p_1 and p_2 who make travel order. When he makes an order by using his smart phone, his pickup and destination locations are sent to the system. Then, the pickup location relative to the drivers and the travel distance is calculated. The p_1 travel distance is 11 kilometers and the p_2 travel distance is 6 kilometers. The pickup distance data of these passengers relative to drivers is shown in Table 3.

Table 3. Driver's Distance Parameter

Driver	$d_{pick}(p_1)$ (km)	$d_{pick}(p_2)$ (km)
m_1	3.5	0.6
m_2	0.5	1.3
m_3	0.1	2.4
m_4	4.5	1.4
m_5	2.3	0.2
m_6	0.7	0.3
m_7	3.2	2.5
m_8	0.3	0.3
m_9	0.1	0.3
m_{10}	1.5	0.6

Table 4. Driver's Price Parameter

Driver	p_{res} (rupiah/km)	p_{target} (rupiah/km)
m_1	1,500	5,000
m_2	3,000	4,000
m_3	2,500	4,500
m_4	1,000	2,000
m_5	1,500	3,000
m_6	3,500	5,500
m_7	2,500	3,000
m_8	2,000	3,200
m_9	2,500	3,500
m_{10}	2,000	2,500

By comparing data in Table 2 and Table 3, the relation is as follows. For passenger p_1 pickup distance parameter, the candidates that can be allocated are $\{m_2, m_3, m_8, m_9, m_{10}\}$. For passenger p_2 pickup distance parameter, the candidates that can be allocated are $\{m_1, m_2, m_4, m_5, m_6, m_8, m_9, m_{10}\}$. Another parameter is the maximum travel distance. Based on maximum travel distance, the drivers that can get the p_1 order are $\{m_3, m_4, m_{10}\}$ while the drivers that can get the p_2 order are $\{m_1, m_2, m_3, m_4, m_7, m_8, m_9, m_{10}\}$. By comparing the pickup distance and the travel distance parameters, the driver that can accept the p_1 order is $\{m_{10}\}$ while the drivers that can accept the p_2 order are $\{m_2, m_4, m_8, m_9, m_{10}\}$.

The next problem is the price. There are two types of price: the target point (p_{target}) and the reservation price (p_{res}). This price is for both the driver and the passenger. The next illustration is the example of the price problem.

Suppose that there are two passengers: p_3 and p_4. The p_3's target point is 1,000 rupiah per kilometer and the reservation price is 2,000 rupiah per kilometer. The p_4's target point is 1,500 rupiah per kilometer and his reservation price is 3,000 rupiah per kilometer. Back to the set of the drivers, the driver's target point and reservation price are shown in Table 4.

By comparing the price range between drivers and passengers, the result is as follows. For passenger p_3, the candidates that can get the order are $\{m_1, m_3, m_4, m_5, m_8, m_{10}\}$. For passenger p_4, the candidates that can get the order are $\{m_1, m_2, m_3, m_4, m_5, m_7, m_8, m_9, m_{10}\}$. The rationale is the candidate's reservation price must be equal to or less than the passenger reservation price.

3. NEGOTIATION AND AUCTION

Negotiation is a process to find solution between parties. Negotiation is needed to solve problem which decision or solution cannot be determined by one party without accommodating other parties' interest. In its basic form, there are three common terms in negotiation process: target point, reservation price, and zone of possible agreement (ZOPA) [9,10]. Zone of Possible Agrrement is also called as settlement zone [11]. Target point is the ideal point for a party. Reservation price is the worst point where party still can make agreement [9]. Reservation price is also called as resistance point [11]. ZOPA is the area or range that the agreement will be done in it. The illustration is shown in Figure 1.

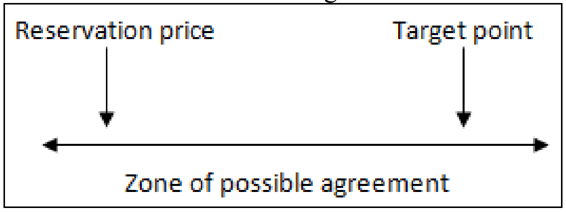

Figure 1. Negotiation Area Basic Concept

Illustration in Figure 1 shows the relation between negotiation terms. This illustration is single party. Common example of negotiation is the price negotiation between merchant and buyer. The merchant's goal is maximizing the price while the buyer's interest is minimizing price. So, in this example, the merchant's target point will be on the right of his reservation price. Meanwhile, the buyer's target price will be on the left of his reservation price. In the online motorcycle taxi context, the driver can be represented as the merchant while the passenger can be represented as the buyer. So, the negotiation illustration between driver and passenger is shown in Figure 2.

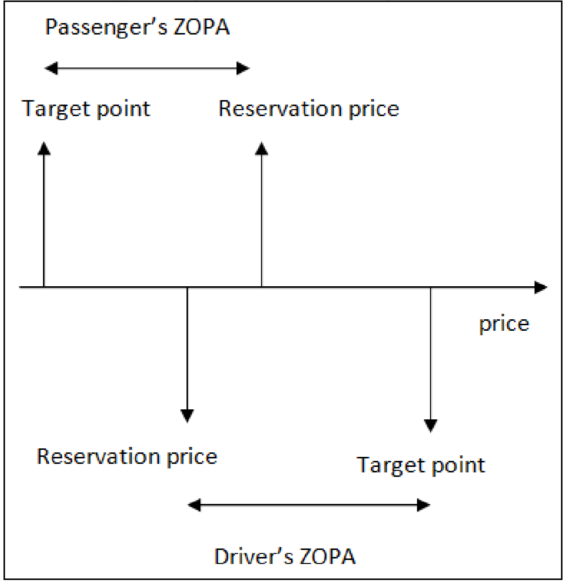

Figure 2. Negotiation Area Between Driver and Passenger

Negotiation can end with agreement or not. There is rule which negotiation will end with agreement [11]. Negotiation will end with agreement if the left party's reservation price is on the right of the right party's reservation price [11].

The example is as follows. Suppose that there is passenger whose target point is 1,500 rupiah per kilometer and reservation price is 2,500 rupiah per kilometer. Now, there are two drivers. The first driver has target point at 4,000 rupiah per kilometer and reservation price at 2,000 rupiah per kilometer. The second driver has target point at 3,500 rupiah per kilometer and reservation price at 3,000 rupiah per kilometer. Based on this situation, negotiation between the passenger and the first driver will end with agreement while negotiation between the passenger and the second driver will end with no agreement.

The rationale of the example above is as follows. In the negotiation between the passenger and the first driver, the passenger's reservation price is on the right of the first driver's reservation price. So, there is intersection area between the negotiating parties. In the negotiation between the passenger and the second driver, the passenger's reservation price is on the left of the second driver's reservation price. So, there is not any intersection area between the negotiating parties.

The agreement success is not affected by the target point position. Target point affects in the opening price and the negotiation duration. Let's back to the previous example. At the beginning, the first driver will open proposed price at 4,000 rupiah per kilometer while the second driver will open proposed price at 3,500 rupiah per kilometer. During the negotiation process, the driver's proposed price will get lower. In the other side, the passenger will open proposed price at 1,500 rupiah per kilometer. During the negotiation process, the passenger's proposed price will get higher. At the certain time, the passenger's proposed price will cross the first driver's proposed price so that the agreement will occur. Meanwhile, for any time, the passenger's proposed price will never cross the second driver's proposed price so that the agreement will never occur.

The other form of negotiation is auction. Auction is a negotiation between seller and buyers or buyers and seller which one party proposes opening price while other parties compete to close the deal by proposing or bidding competitive price. The opening price is usually the reservation price. When the bidding sequence runs, the end price may exceed other party's target point. The passenger-drivers auction illustration is shown in Figure 3.

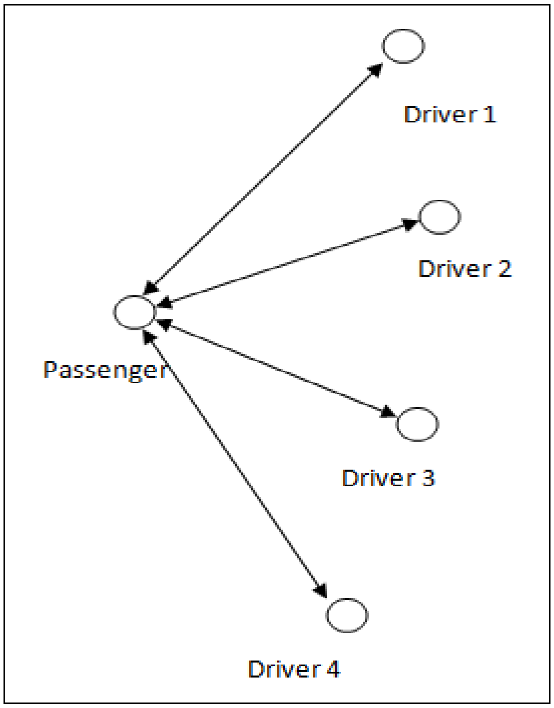

Figure 3. Passenger-Driver Auction

As it is mentioned in negotiation process, auction may end with agreement or no agreement. Agreement will reach if there is minimum one bidder who proposes price. The last bidder who propose price will win the auction. In other hand, if there are not any bidders who propose price then the auction will end with no agreement.

The main common type of auction is sealed bid auction. In this form, bidder submits his proposal without knowing other bidders' proposal [12]. Besides this term, based on the winner, auction can be divided into two types: first price auction and second price auction [12]. In the first price auction, the highest bidder becomes the auction winner and the deal price is the price that is proposed by him [12]. Meanwhile, the second price auction is similar to the first auction winner. But, the price that must be paid is the price that is proposed by the second highest winner [12].

Klemperer explained that there are four basic types of auctions: ascending bid auction, descending bid auction, first price sealed bid auction, second price sealed bid auction [13]. The ascending bid auction is also called as English auction [13]. Descending bid auction is also called as Netherland or Dutch auction [13]. The last two types of auction are also called as Vickrey auction [13].

There are several other auction models. The first model is one party proposes the opening price. Then, other parties who have willingness to bid will propose price. The best proposed price will win the auction. Bidder cannot resubmit price. This is single round auction. The example is as follows.

Suppose that there is passenger that creates travel order. He opens the price at 1,000 rupiah per kilometer. Then, there are five drivers $\{m_1, m_2, m_3, m_4, m_5\}$ that receive the travel order and the proposed price. These drivers then submit their offering prices at {3,000; 2,500; 1,700; 1,800; 2,100} rupiah per kilometer consecutively. Because this is a single round auction, then the passenger has only two options: reject or accept. In this case, the lowest driver offering price is 1,700 and it is belong to driver m_3. If the passenger's reservation price is equal or higher than the lowest offering price, for example it is at 2,500 rupiah per kilometer, the passenger will accept the proposal and driver m_3 will win the auction. Meanwhile, if the passenger's reservation price is lower than the lowest offering price, for example it is at 1,500 rupiah per kilometer, the passenger will reject the proposal and the auction will end with no agreement.

The situation is different if this is a multi round auction. As it is mentioned above, suppose that in the first bidding round, the lowest proposing price is 1,700 rupiah per kilometer. Suppose that the second bidding round is now open. The next proposed price should be lower than 1,700 rupiah per kilometer. Because of driver m_1 and m_2's reservation price is above 2,000 rupiah per kilometer then only driver m_3, m_4, and m_5 submit new offering price in the second bidding session. These new proposed prices are {1,600; 1,500; 1,400} consecutively. Now, the lowest proposed price is at 1,400 rupiah per kilometer and it is belong to driver m_5. Then, the third bidding round is open. Because the m_4 and m_5's reservation price is at 1,500 rupiah per kilometer then these drivers do not submit the offering price. Driver m_4 also do not submit the offering price because his reservation price is at 1,400 rupiah per kilometer. Because there are not any drivers who submit the proposal, then the bidding session is end. Because the lowest offering price is at 1,400 rupiah per kilometer and this price is belong to driver m_5 then this driver becomes the auction winner at 1,400 rupiah per kilometer price level.

4. PROPOSED MODEL

Based on that condition, in this paper, we propose new online motorcycle taxi dispatch model based on auction model. The proposed model is developed based on two novelties so that this research is the improvement of the previous model. The first novelty is that this model adopts multi agent system which in this model, the driver's and passenger's interests are accommodated. In the previous agent based model, parameters that are concerned are the safety and driver bravery [5]. Meanwhile, in this research, parameters that are included in the multi agent system is passenger's maximum waiting time, driver's maximum pickup and travel distances, and price level.

The second novelty of this research is the adoption of the auction method. Auction based model has not been adopted in any researches in automatic online taxi dispatch system yet. It is because many taxi dispatch models are dominated by nearest driver model [7,14,15] or FIFO model [16,17].

In this system, there are two agent types: drivers and passengers. There are three models in this research. In the first models, parameter in the auction is the number is the maximum pickup distance. In the second models, parameter in the auction is the number of maximum travel distance. In the third models, parameter in the auction is the combination between maximum pickup distance and maximum travel distance. These pickup and travel distance are the driver's interest. Meanwhile, the passenger's interests that are accommodated in these models are waiting time (t_{wait}) and price. The passenger's waiting time is calculated by using Equation 1. In the Equation 1, the d_{pickup} is the pickup distance and the v is the vehicle speed. Based on the passenger's view, it does not matter how far the driver's current position from the pickup location as long as the waiting time is still equal or under the passenger's maximum waiting time ($t_{maxwait}$). So, it is contradicted with the previous work which used observation range to limit pickup distance.

$$t_{wait} = \frac{d_{pickup}}{v} \qquad (1)$$

There are two steps that are required in all proposed models in this paper. The first step is finding driver's candidate. The second step is dispatching the order to the candidate. This process is executed sequentially. The main algorithm of this process is shown in Figure 4.

```
Begin
  C ← find_candidate(M)
  if n(C) > 0 then
    $m_{sel}$ ← dispatch(C)
  else
    fail
end
```

Figure 4. Main Process Algorithm

In the main process algorithm, some variables and function are used. Variable C represents the set of driver candidates so that the n(C) is the number of the C set members. Variable M represents the set of drivers in the system. Variable m_{sel} represents the driver that is selected to execute the order. The find_candidate function represents the first step. The dispatch function represents the second step. It is shown that the number of C set members is more than 0 then the process continue to the second step. Otherwise, the system fails to find candidate.

The difference between the first, the second, and the third proposed models are in the candidate finding processes. There are three requirements for every model so that driver in the system can be a candidate: price requirement, waiting time requirement, and distance requirement. But, there are similarities similarities among models. The similarities are the reservation price requirement and waiting time requirement. In all models, the driver's reservation price must be lower than or equal to the passenger's reservation price. This requirement is represented in Equation 2. In Equation 2, variable s_{price} represents the price requirement status.

$$s_{price} = \begin{cases} 1, m_{res} \le p_{res} \\ 0, else \end{cases} \qquad (2)$$

Besides price requirement status, the waiting time requirement status must be calculated too. The price requirement status is determined by using Equation 3. In Equation 3, variable s_{wait} represents the waiting time requirement status. Meanwhile, the $t_{maxwait}$ represents the maximum waiting time. So, based on this formula, the waiting time requirement status will be 1 only if the waiting time is equal to or lower than the maximum waiting time.

$$s_{wait} = \begin{cases} 1, t_{wait} \le t_{\max wait} \\ 0, else \end{cases} \qquad (3)$$

Besides price requirement and waiting time requirement statuses, the distance requirement status must be calculated too. The distance requirement status is represented by using variable $s_{distance}$. The driver will become a driver candidate for the order if this driver is available and his both price requirement status and distance requirement status is 1. This process is represented in candidate finding algorithm that is shown in Figure 5.

The explanation of the candidate finding algorithm is as follows. For the first time, the candidate set is cleared. Then, the process iterates from the first driver to the last driver in the system. The driver availability status is represented by using variable s_{av}. If the driver is available then the status is 0. Otherwise the status is 1. The calc_sprice function is used for calculating the price requirement status. The calc_sdistance function is used for calculating the distance requirement status. The calc_swait function is used for calculating the waiting time requirement status. All statuses then are summed and the result is stored in variable s_{tot}. If all requirement statuses are 1 then this driver will added to the candidate set. So, if there is not any driver who joins into the candidate set then the number of its member will be zero.

```
begin
 C.clear()
 for i = 1 to n(M)
 begin
  if $s_{av,i}$ = 0 then
  begin
   $s_{price,i}$ ← calc_sprice($m_i$)
   $s_{distance,i}$ ← calc_sdistance($m_i$)
   $s_{wait,i}$ ← calc_swait($m_i$)
   $s_{tot,i}$ ← $s_{price,i}$ + $s_{distance,i}$
   if $s_{tot,i}$ = 3 then
    C.addmember($m_i$)
  end
 end
end
```

Figure 5. Candidate Finding Algorithm

In the first proposed model, the distance parameter that is calculated is the driver's pickup distance. In this model, the driver's pickup distance must be equal to or lower than his maximum pickup distance. The distance requirement status is determined by using Equation 4 to Equation 6.

$$d_{pickup} = \left\| p_{pickup} - p_m \right\| \tag{4}$$

$$s_{pickup} = \begin{cases} 1, d_{pickup} \le d_{\max pickup} \\ \quad 0, else \end{cases} \tag{5}$$

$$s_{dis\tan ce} = s_{pickup} \tag{6}$$

The explanation of these equations is as follows. In Equation 4, the pickup distance (d_{pickup}) is the Euclidean distance between pickup location (p_{pickup}) and driver's current location (p_m). Then, in Equation 5, the pickup status will be 1 only if the pickup distance is equal to or lower than the driver's maximum pickup distance ($d_{maxpickup}$). Otherwise, the pickup status is 0. In Equation 6, it is shown that in this model, the distance requirement status is the pickup status.

In the second proposed model, the distance requirement status is the travel distance. The travel distance must be equal to or lower than the driver's maximum pickup distance. The distance requirement status of the second proposed model is determined by using Equation 7 to Equation 9.

$$d_{travel} = \left\| p_{dest} - p_{pickup} \right\| \tag{7}$$

$$s_{travel} = \begin{cases} 1, d_{travel} \le d_{\max travel} \\ \quad 0, else \end{cases} \tag{8}$$

$$s_{dis\tan ce} = s_{travel} \tag{9}$$

The explanation of these equations is as follows. In Equation 7, the travel distance (d_{travel}) is the Euclidean distance between destination location (p_{dest}) and pickup location (p_{pickup}). Then, in Equation 8, the travel status will be 1 only if the travel distance is equal to or lower than the driver's maximum travel distance ($d_{maxtravel}$). Otherwise, the travel status is 0. In Equation 9, it is shown that in this model, the distance requirement status is the travel status.

In the third proposed model, the distance requirement status is calculated based on the pickup status and the travel status. All of these statuses must be 1. Otherwise the distance requirement status will be 0. The pickup status is determined by using Equation 5. The travel status is determined by using Equation 6. Meanwhile, the distance requirement status is determined by using Equation 10.

$$s_{dis\tan ce} = \begin{cases} 1, s_{pickup} = 1 \wedge s_{travel} = 1 \\ \quad 0, else \end{cases} \tag{10}$$

After finding the candidate, the next step is allocating the order to the certain driver. In this step, auction method is implemented. In our proposed model, the type is sealed single round auction. It means that driver can propose once and cannot resubmit price proposal. The benefit of this method is the auction process will be simpler and faster. But, the driver has only one chance to submit proposal.

This dispatch step is divided into two sub steps: proposal submission and price finalization. These sub steps are done sequentially. In the proposal submission, every candidate will send price proposal. Then, the system will decide the auction winner. After the winner is decided, the next step is determining the final price. The price that is proposed by the winner must be adjusted with the passenger's interest.

In proposal submission step, each driver will send his price proposal. In the auction model, we use variable p as price even we have used variable p as location in the previous step. The proposed price that is submitted by the driver is represented by using variable p_{prop}. The winner of auction is the driver who proposes the lowest price. The formula is described in Equation 11 and the process is shown in Figure 6.

$$m_{sel} = m \mid m \in C \wedge \min\left(p_{prop}\right) \qquad (11)$$

```
begin
 cursel ← 1
 $p_{min}$ ← $p(m_{cursel})$
 for j = 2 to n(C)
 begin
  if $p(m_j)$ < $p_{min}$ then
  begin
   $p_{min}$ ← $p(m_j)$
   cursel ← j
  end
 end
 $m_{sel}$ ← $m_{cursel}$
end
```

Figure 6. Winner Decision Process Algorithm

The explanation of the algorithm is as follows. Variable cursel stores the index of the current selected merchant. Variable p_{min} stores the current minimum price. So, at the beginning, the current selected merchant is the first merchant in set C. Then, there is looping process from index 2 to the number of set C. For each iteration, the process check whether the the current indexed driver proposes lower price. If the current indexed driver proposes lower price, then he will be the current selected driver and his price will be the current lowest price. After the looping is ended, the current selected driver will be the selected driver.

After the selected driver is determined, the next step is finalizing the price. This driver's proposed price may be higher than the passenger's reservation price. To make it fair, the final price must accommodate both parties: driver and passenger. In this model, the final price is in the middle between the driver's reservation price and the passenger's reservation price. This formula is described in Equation 12 and Equation 13.

$$p_{final} = p_{res\_driver} + \frac{\Delta p_{res}}{2} \qquad (12)$$

$$\Delta p_{res} = p_{res\_passenger} - p_{res\_driver} \qquad (13)$$

There are new variables in Equation 12 and Equation 13. Variable p_{final} is the final price. Variable p_{res_driver} is the driver's reservation price. Variable $p_{res\_passenger}$ is the passenger's reservation price. Variable Δp_{res} is the difference between passenger's reservation price and driver's reservation price.

Based on Equation 12 and Equation 13, it is hoped that there is fairness in final price. When the passenger's reservation price is higher than driver's reservation price, the final price will be higher than the driver's reservation price and lower than the passenger's reservation price. Meanwhile, when the driver's reservation price is equal to the passenger's reservation price then the final price is at both reservation prices.

5. IMPLEMENTATION

These three proposed model then is implemented into online motorcycle taxi dispatch simulation application. The world of the simulation is a virtual city. Its size is 20 kilometer width and 20 kilometer length. Passengers and drivers are distributed uniformly in the city. The application is not time variant simulation.

The simulation scenario is as follows. At the beginning, some passengers and drivers are generated in the application. All parameters that are related to these entities are generated too. Parameters that are related to the passengers are: maximum waiting time, reservation price, target point, pickup location, and destination location. Parameters that are related to the driver are: current location, maximum pickup distance, maximum travel distance, speed, reservation price, and target point. These parameters are generated randomly.

After all of these parameters are set then the dispatch process runs. The dispatch process iterates from the first to the last order. If the dispatch process is success then the order status is set success. Otherwise, the order status is set fail. In the end of the application, the success ratio ($r_{success}$), which is the ratio between the number of success orders and the number of total order are calculated. Besides that, the other observed parameters are: driver's total revenue, passenger's total waiting time, and driver's total pickup distance.

6. DISCUSSION

After the proposed model is implemented into simulation application, then these three proposed models are tested to evaluate their performance. These proposed models are compared to each other. Besides, the previous nearest driver model is tested too so that the performance of these proposed models is also compared with the previous model [6]. The simulation evaluates the relation between the increasing number of passengers and the observed parameters.

In this simulation, the number of drivers is set 500 drivers. The number of passengers is set from 10 to 100 passengers. The adjusted parameters are set default. The default value of these adjusted parameters is shown in Table 5. In previous model, the driver's price is 2,000 rupiah per kilometer.

The first result is the driver's success ratio. As it is mentioned above, the success ratio is the ratio between the number of success order and the number of total orders. The result is shown in Table 6. The result is collected from the first model, the second model, the third model, and the previous nearest driver model. To make it is observed easier, the data trend is also shown in Figure 7.

Table 5. Adjusted Parameters Default Value

Parameter	Default Value
$t_{maxwait}$	10 minutes
$p_{res\_passenger}$	4,000 rupiah/km
$p_{target\_passenger}$	1.500 rupiah/km
d_{max_pickup}	3 km
d_{max_travel}	12 km
v	0.5 km/minute
p_{res_driver}	1,500 rupiah/km
p_{target_driver}	5,000 rupiah/km

Table 6. Driver's Success Ratio Result

n_p(unit)	First Model (%)	Second Model (%)	Third Model (%)	Nearest Driver Model (%)
10	72.7	77.3	35.5	100.0
20	50.5	77.0	24.5	100.0
30	46.5	74.3	24.0	100.0
40	38.1	72.0	18.4	100.0
50	32.2	67.5	19.2	100.0
60	25.4	61.7	14.0	100.0
70	23.0	59.4	13.5	100.0
80	19.8	61.2	11.8	100.0
90	18.8	54.8	12.4	100.0
100	17.9	58.6	11.1	100.0

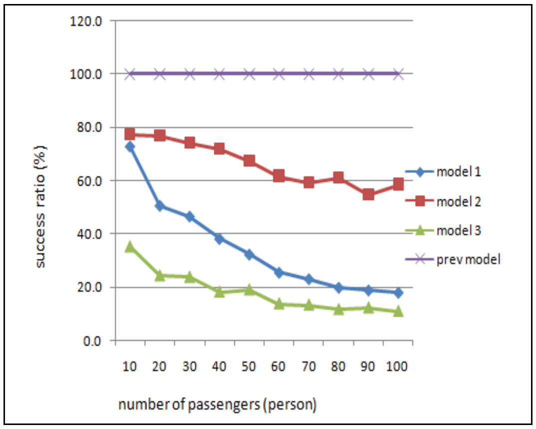

Figure 7. Success Ratio

Based on data in Table 6, it is shown that by using all of the proposed models, the driver's success ratio never reaches 100 percents. It means that there are some passengers that cannot get the driver to execute their orders. When the number of passengers increases, the driver's success ratio decreases. This condition is different when dispatch system uses previous nearest driver model [6]. By using this model, the driver's success ratio is always 100 percents. It means that all of passenger orders are executed successfully.

The reason is as follows. When the system implements these proposed models, there are many interests that must be accommodated. So, when these interests are not accommodated, there are not any driver will execute order. The condition is different with the nearest driver model [6]. Because there is not any distance limitation, as long as there is available driver in the system, the order will be executed even the pickup distance is very far.

Based on data in Figure 7, the comparison among proposed models in driver's success ratio is as follows. The second model performs the highest success ratio. The third model performs the lowest success ratio. The first model performs in the middle. When the number of passengers is low, the success ratio of the first model is close to the success ratio of the second model. When number of passenger increases, the success ratio of the first model declines faster than other proposed models. When the number of passenger is high, the success ratio of the first model is close to the success ratio of the third model.

The second result is driver's total revenue. The result is shown in Table 7. The result is collected from the first model, second model, third model, and the previous nearest driver model. The data trend is also shown in Figure 8.

Table 7: Total Driver's Revenue Result

n_p(unit)	First Model (rupiah)	Second Model (rupiah)	Third Model (rupiah)	Nearest Driver Model (rupiah)
10	380,932	359,245	196,977	335,091
20	454,325	573,195	201,175	613,400
30	653,755	839,605	273,240	926,600
40	788,585	1,210,895	338,185	1,313,000
50	793,005	1,339,180	357,415	1,588,000
60	635,275	1,376,190	242,720	1,890,200
70	748,160	1,709,365	295,785	2,205,600
80	718,050	1,910,855	337,345	2,491,400
90	808,470	1,989,755	438,085	2,862,000
100	934,240	2,304,865	435,075	3,150,000

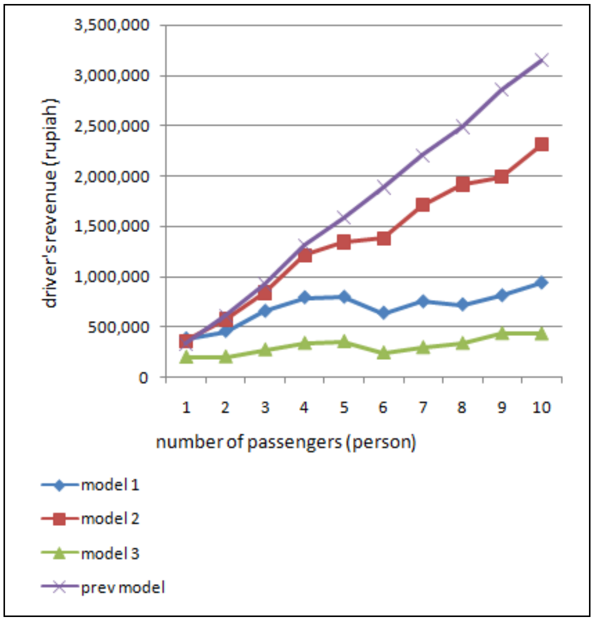

Figure 8. Driver's Revenue

Based on data in Table 7, it is shown that the system produces the highest total revenue when it implements nearest driver model. In the other side, the system produces the lowest total revenue when it implements the third proposed model. Meanwhile, the revenue that is generated by the first and the second model are between them with the revenue of the second model is higher than the revenue of the first model. This condition is the consequence of the success ratio. Comparing to each other, it is shown that driver's success ratio has positive correlation with the total driver's revenue.

Based on data in Figure 8, it is shown that at the beginning, the revenue gap among models is narrow. During the increasing of the number of passenger, the revenue gap among models is wider. It is because during the increasing of the number of passenger, the success ratio gap is wider too and it causes the wider gap in total driver's revenue.

Even these proposed models produce lower total revenue than the previous model does, the average revenue that is generated by using these proposed models is higher than by using the previous model [6]. Let's take example when the number of passenger is 100 persons. The dividing the total revenue with the success ratio, the result is as follows. The first model average revenue is 52,192 rupiah per order. The second model average revenue is 39,332 rupiah per order. The third model average revenue is 39,195 rupiah per order. The previous model [6] average revenue is 31,500 rupiah per order.

Based on this data, the first model produces the highest average driver revenue among all models. Then, it is followed by the second and the third model. The average revenue gap between the second and the third model is very tight. Meanwhile, the previous nearest driver model produces the lowest average driver revenue.

The reason of this condition is as follows. In the first model, the travel distance is not limited. So, driver can get high travel distance order. This condition is different to the second and the third models. In these models, the travel distance limitation is applied. So, only medium or low travel distance order that can be allocated to the driver. Meanwhile, the condition in the previous nearest driver model is different. In this model, fix tariff is applied and all orders get same price at 2,000 rupiah per kilometer. This price is close to the driver's reservation price.

The third result is passenger's total waiting time. The result is shown in Table 8. The result is collected from the first model, second model, third model, and the previous nearest driver model. The data trend is also shown in Figure 9.

Table 8: Total Passenger's Waiting Time

n_p(unit)	First Model (minute)	Second Model (minute)	Third Model (minute)	Nearest Driver Model (minute)
10	47	75	22	83
20	82	140	34	201
30	117	225	60	392
40	150	303	62	551
50	155	343	80	781
60	168	402	75	1,075
70	188	489	103	1,371
80	171	549	85	1,567
90	185	577	106	1,932
100	191	645	104	2,078

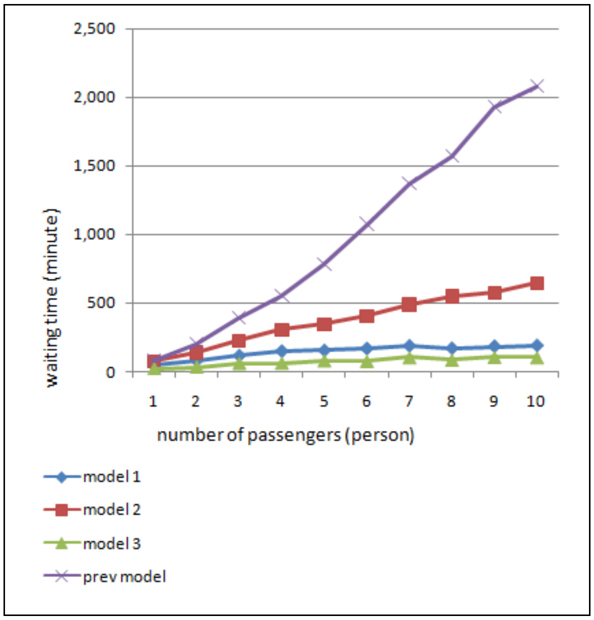

Figure 9. Passenger's Waiting Time

Based on data in Table 8, it is shown that in total passenger's waiting time aspect, the nearest driver model performs the highest one. Meanwhile, the third proposed model performs the lowest one. The first and the third models are in the middle with the waiting time of the first model is higher than waiting time of the third model. This condition is related to the driver's success ratio. The success ratio has positive correlation with the total passenger's waiting time.

Based on data in Figure 9, it is shown that the number of passenger affects the waiting time gap among models. When the number of passenger is low, the gap between the highest and the lowest waiting time is narrow. When the number of passenger increases, the gap is wider.

The next analyzes is the average passenger's waiting time. The example is the waiting time when the number of passenger is 100 persons. The average waiting time is gotten by dividing the total waiting time with the success ratio. The average waiting time of the first model is 10.6 minutes. The average waiting time of the second model is 11 minutes. The average waiting time of the third model is 9.4 minutes. The average waiting time of the fourth model is 20.8 minutes.

Based on this result, it is shown that when the system implements nearest driver model, the average waiting time is the highest. The lowest result is reached when the system implements the third model. The average waiting time of the first and the second models are in the middle with the first model performs lower than the second model does.

The fourth result is driver's total pickup distance. The result is shown in Table 9. The result is collected from the first model, second model, third model, and the previous nearest driver model. The data trend is also shown in Figure 10.

Table 9:Driver's Total Pickup Distance Result

n_p(unit)	First Model (%)	Second Model (%)	Third Model (%)	Nearest Driver Model (%)
10	27	75	14	21
20	41	148	17	60
30	66	229	34	103
40	66	293	28	149
50	72	329	38	214
60	66	367	34	282
70	78	437	45	355
80	71	511	40	418
90	76	528	50	501
100	77	594	44	582

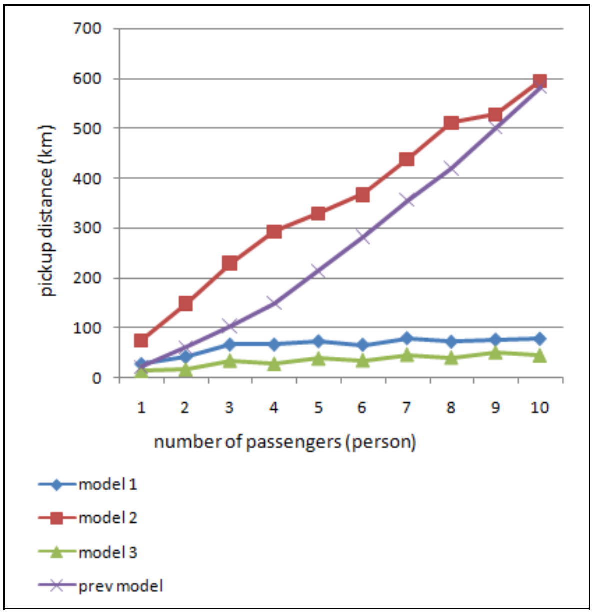

Figure 10. Pickup Distance

Based on data in Table 9, it is shown that in total pickup distance aspect, the second model performs the highest one. Meanwhile, the third model performs the lowest one. The previous model performs lower than the second model does but the gap between them is close. The first model performs higher than the third model but the gap between them is low.

As it is shown in Figure 10, the correlation between the number of passenger and the total pickup distance is depended on the model that is implemented. When the system implements the second model or the previous model, the number of passenger has positive correlation with the total pickup distance with significant influence. Meanwhile, when the system implements the first model or the third model, the number of passenger has less significant influence to the total pickup distance.

The next analyzes is the average pickup distance. The example is the average pickup distance when the number of passenger is 100 persons. The result is gotten by dividing the total pickup distance with the success ratio. The average pickup distance of the first model is 4.3 kilometers. The average pickup distance of the second model is 10.1 kilometers. The average pickup distance of the third model is 3.9 kilometers. The average pickup distance of the previous model is 5.82 kilometers.

Based on this result, it is shown that the third model performs the lowest average pickup distance. This performance is followed closely by the first model. Then, the second model performs the worst pickup distance. Meanwhile, the previous model [6] performs moderate.

7. CONCLUSION AND FUTURE WORK

Based on the explanation above, the proposed model has been developed and implemented into online motorcycle taxi dispatch simulation. The model is developed based on auction method and accommodates both driver interest and passenger interest. The interests that are accommodated in this model are: reservation price, target point, waiting time, pickup distance, and travel distance. In this research, we propose three models. The first model accommodates the pickup distance interest. The second model accommodates the travel distance interest. The third model accommodates both pickup distance and travel distance. In all models, the price range and waiting time are accommodated. In all models, the sealed single round auction implemented where the winner is driver meets all requirements and submits the lowest price.

These proposed models then being tested to evaluate their performance. The observed variables are: success ratio, revenue, waiting time, and pickup distance. Performance of these models is also compared with performance of the previous nearest driver model.

Related to the hypothesis that is mentioned in the first chapter, the conclusion is as follows. Among all proposed models, some models perform better than the previous nearest driver model while other models perform worse. In some parameters, the proposed models perform better than the previous nearest driver model while in other parameters, the proposed models perform worse. The detailed conclusion is explained in the research finding below.

The research finding is as follows. In success ratio aspect, the nearest driver model performs the best and it is followed by the second model, the first model, and the third model consecutively. In average driver revenue aspect, the first model performs the highest average driver revenue and it is followed by the second model, the third model, and the previous model consecutively. In average waiting time aspect, the third model performs the lowest average waiting time aspect and it is followed by the first model, the second model, and the previous model consecutively. In average pickup distance aspect, the third model performs the lowest average pickup distance and it is followed by the first model, the previous model, and the second model.

This research triggers other research potentials. As the online motorcycle taxi business is still growing, its business model is still improved. Dispatch mechanism is more complex too because stakeholder's needs are more complex too. Related to this research, the auction model that is implemented in this model is not the only auction model. For example, multi round auction based mode will be very interesting to be implemented so that the performance between auction models can be compared. In a broader view, auction is small part of negotiation model. Implementing other negotiation model in the online motorcycle taxi dispatch system is also challenging.

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