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MULTI PARAMETERS DISPATCH MODEL IN TAXI COLLABORATION SYSTEM

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ABSTRACT

Nowadays, conventional taxi business meets strong competition with the online taxi service. One of the problem is that in online taxi service that adopts sharing economy platform, public can join to be a driver easily as far as he owns the vehicle. So, there are large number of vehicles are in the online taxi service. This condition is different to the existing conventional taxi that is operated by private company and the vehicles are owned by the taxi company. Even the taxi company is a big corporate, it still cannot compete with the online taxi service. The answer is developing collaboration between taxi companies so that the service is operated by a single system. Unfortunately, creating collaboration system among taxi companies is not easy. It is because the number of fleets that are owned between companies is various. The other problem is that each company has its own pricing strategy. In this research, we propose the dispatch model for conventional taxi collaboration system. Parameters in this model are travel cost, pickup distance, vehicle's idle time, and the fleet size. In this research, we propose three models. In the first model, order will be allocated to the vehicle that offers the lowest travel cost and has longest idle time. In the second model, order will be allocated to the vehicle that offers the lowest travel cost but the model does not guarantee that longer idle time vehicle will be preferred. In the third model, the order will be allocated to the vehicle that has the highest aggregate score of travel cost, pickup distance, idle time, and fleet size. Based on the simulation result, the first and the second models has advantage in offering the lowest travel cost while the third model has advantage in keeping pickup ratio at maximum level.

Keywords: *Dispatch system, Taxi, Collaboration, Simulation, Nearest Driver.*

1. INTRODUCTION

Nowadays, conventional taxi industry meets fierce competition with the online taxi service [1-4]. By offering lower travel cost, there is customer shifting from using conventional taxi to online taxi. In some area, this condition forces the traditional taxi company to reduce its fleet [1]. This condition occurs in many countries. This condition also occurs in Indonesia. Many conventional taxi companies decline or end their operation. This condition triggers resistance from the conventional taxi drivers. Even the conventional taxi faces strong competition, there are opportunities to survive. The online taxi still has weakness. Because of the travel cost is low, for several drivers, they turn back to the conventional one [3]. The long term survival capability of the online taxi is still questioned [4].

There are benefits that are offered by the online taxi service that cannot be offered by the conventional taxi service. First, passenger can order vehicle easily by using mobile application [5]. Second, online taxi service offers fixed travel price. Third, passenger can get vehicle easier because the online taxi service offers large number of vehicles because of the sharing economy concept [2].

In conventional taxi system, basically passenger can order taxi by three ways: hailing on the street, going to taxi pool, or ordering by phone [6]. The problem in ordering by phone is that the passenger must describe his pickup location and sometimes, the location cannot be found easily. In the other hand, after receiving the order, the customer service will search for available vehicle manually. If he cannot find any available vehicle, he will confirm to the passenger. Meanwhile, in online taxi service, the vehicle allocation process is done automatically by system. By creating order through mobile application, precise pickup and destination locations are sent to the system because the smart phone is equipped by GPS and is supported by Google Map. So, passenger can get the result whether he is success or fail in getting vehicle. This system makes the booking process simpler and easier.

In conventional taxi system, final travel cost is determined after the passenger arrives to the destination. It is because the total cost is divided into two parts, fix cost and variable cost. Fix cost is applied for certain first miles. Variable cost is applied after certain fist miles until the last miles. In other version, taxi rate can be divided into three categories: base rate, charge per mile, and charge per minute [7]. In conventional system, the distance between pickup location and destination location cannot be determined when the order is made. The total distance is determined when the vehicle arrives at the destination. Due to various traffic conditions, the price can rise fast and it cannot be predicted previously. This condition is different to the online taxi system. In online taxi system, passenger must determine his pickup and destination locations. By sending his precise locations to system, so the system can calculate the total cost immediately. The location is based on GPS location. Because this data is sent while he creates order, the total travel cost can be determined immediately after the order is created.

Basically, online taxi service is a middle party that connects the passenger to the available vehicles that join the system. So, this company does not have even a single vehicle to be transported as sharing economy concept [5]. This is an open system so that vehicle owners can join into the system easily. The result is large number of vehicle owners join the system. The opposite condition occurs in conventional taxi system. Basically, the vehicles are owned by the company. The consequence is that the conventional taxi cannot beat the online taxi, especially in number of fleets. Each company has limited resource to provide more vehicles.

The other problem is the driver availability. In conventional taxi system, most of drivers are the company employee and they will receive salary even fix and variable ones. For conventional taxi company, recruiting more drivers must be calculated more precisely because the consequence of the increasing of operational cost. In the other hand, for online taxi service, driver is treated as partner. It means that there is not any salary that must be provided by the company for the driver. The driver's revenue is based on the driver portion of the passenger travel cost and company revenue is based on the company commission part. So, for the online taxi service, recruiting more drivers is easier. The company can focus on maintaining and balancing between passenger waiting time and driver idle time [10].

Fortunately, there are usually more than one conventional taxi companies in a city in Indonesia, especially in medium or big city like Jakarta, Bandung, Surabaya, or Yogyakarta. So, even an online taxi company outnumbers a conventional taxi company in number of fleets, by the collaboration of all or many taxi companies in a city, the conventional taxi companies can outnumber the online one so that the conventional taxi company is still competitive.

Unfortunately, developing the collaboration between taxi companies is not easy. First, every taxi company has its own management and strategy, especially in pricing and dispatch management. Second, the number of the fleets between taxi companies is various. Third, they have competition history in the past that sometimes taxi driver in one company gives negative perception to the passenger about other taxi company.

Based on these conditions, the motivation of this research is to explore, develop, and propose any methods or models that can be implemented into conventional taxi system so that conventional taxi can perform better than now, especially in efficiency aspect even in financial and non financial parts. It is because even nowadays, the online based taxi performs better than the conventional one, in some aspects, such as standard operation procedure, driver's attitude, vehicle standard, and others, conventional taxi is better than the online one. We hope that the improvement may avoid the conventional taxi from extinction because it will be very costly because large number of resources, such as vehicles, drivers, and other employees will be wasted.

Based on these problems, in this work, the main research question is how to develop dispatch model in a taxi collaboration system. The other research question is how efficient the proposed model performance comparing with the existing model or with the previous model. The dispatch model must concern in those critical parameters so that the dispatch model can benefits all of the stakeholders: passenger, driver, and company.

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Based on this research question, the research purpose is developing the dispatch model in a taxi collaboration system that benefits the all of the stakeholders. Another purpose is to evaluate the proposed model performance, both in non financial and financial aspects. This paper is also the continuation of the previous works [8,9]. In the previous works, we explore the online based taxi, especially in multi agent approach [8] and the mandatory approach [9]. Now, we focus on the conventional side.

This research is done based on specific method and steps. First, we observe and analyze the existing conventional taxi condition to find and formulize the problems. Second, we review literatures, especially in taxi system and our previous works as basis for proposing solution or model. Third, we propose collaborative model with several options. Fourth, we implement these proposed models in taxi simulation application so that the application can simulate the condition and performance of the model. Fifth, we do several tests by using the simulation application to observe and evaluate the proposed models, comparing the performance to each other and with models from previous works. Sixth, we conclude the research and gather the research finding.

This paper is organized as follows. In section one, we explains the background, research question, research purpose, and paper organization. In section two, we describe the problem in taxi collaboration system. In section three, we explain the proposed model. In section four, we explain the implementation of the proposed model into taxi collaboration system simulation. In section five, we explain and analyze the test result and the research finding based on the result data. In section six, we conclude the work and explain the future research potential.

2. PROBLEM IN TAXI COLLABORATION SYSTEM

In this section, we will explain the condition and problem that occurs in taxi collaboration system. But, before we explain further, for simplicity, we will explain the basic condition in monopolistic environment, where all of taxi vehicles in some area are managed by single company. Suppose that even this is still a conventional taxi company, the order is made by application. The illustration is shown in Figure 1.

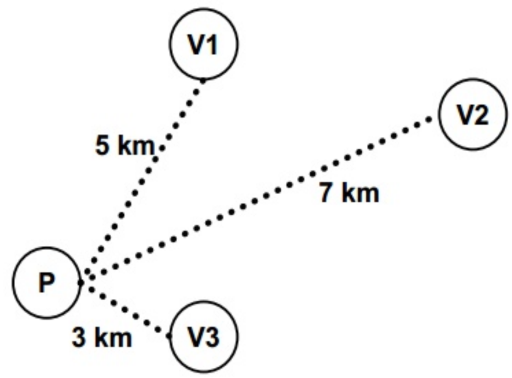

Figure 1. Single Company Taxi Environment

Based on the illustration in Figure 1, there is a passenger that wants to order taxi by using application. This application is provided by the taxi company. In the environment, there are three available vehicles near the passenger that are owned by the taxi company: $\{v_1, v_2, v_3\}$. Each vehicle has certain distance to the passenger, where $\{r_1,r_2,r_3\}$ is $\{5,7,3\}$. Based on the previous work, there are three dispatch models that can be chosen. The first method is nearest driver method. The second method is FIFO method. The third method is the combination between nearest driver and FIFO method.

These three methods can generate different result to each other. While the system uses the first method, the order then is allocated to v_3 because its location is the closest to the passenger. If system adopts the second method, then new parameter is needed. This new parameter is the driver's idle time. Suppose that driver's idle time is $\{45,120,30\}$ seconds. By using the second method, the order will be allocated to v2 because its idle time is the highest among others. If the third method is implemented, the result still can be calculated because the allocation process is determined by the weighted score between two parameters.

The next problem is a situation that there are more than one taxi companies in the environment. For example, suppose that there are eight vehicles in the environment $\{v_1,v_2,v_3,\ldots,v_8\}$. These vehicles are owned by three companies $\{c_1, c_2, c_3\}$. These three companies have their own travel unit cost. The mapping between vehicles and companies is shown in Table 1. The travel unit cost for each vehicle is shown in Table 2. In the environment, there is a passenger that books the travel order. The distance between the passenger and the vehicles is shown in Table 3. The illustration is shown in Figure 2.

Table 1. Mapping Between Vehicles and Companies

Vehicle	Company
v_1	c_1
v_2	c_1
v_3	c_1
v_4	c_2
v_5	c_2
v_6	c_3
v_7	c_3
v_8	c_3

Table 2. Travel Unit Cost

Company	Travel Unit Cost (rupiah)
c_1	4,000
c_2	3,500
c_3	4,200

Table 3. Distance Between Passenger and Vehicles

Vehicle	Distance (km)
v_1	0.4
v_2	0.2
v_3	1.3
v_4	1.1
v_5	0.9
v_6	0.1
v_7	0.6
v_8	1.4

In this case, the passenger will travel to the location which its distance from the pickup location is 10 kilometer. Based on this condition, there are options that can be chosen with their own consequence. If the system adopts shortest driver model then this order will be allocated to v_6 but the travel cost will be 42,000 rupiah. If the system adopts the lowest price then this order will be allocated to v_5 because this company provides the lowest travel unit cost and between vehicles with same company and has shortest distance to the passenger. It means system adopts the shortest path among the lowest cost. So, the passenger must pay 35,000 rupiah only. Unfortunately, even v_5 vehicle provides the lowest travel cost, there are five other vehicles which the distance between each of them and the passenger is the nearer than the v_5. The distance between v_5 and the passenger is nine times from the distance between v_6 and the passenger. Based on the problems above, there is condition whether the system tends to benefit passenger or vehicle.

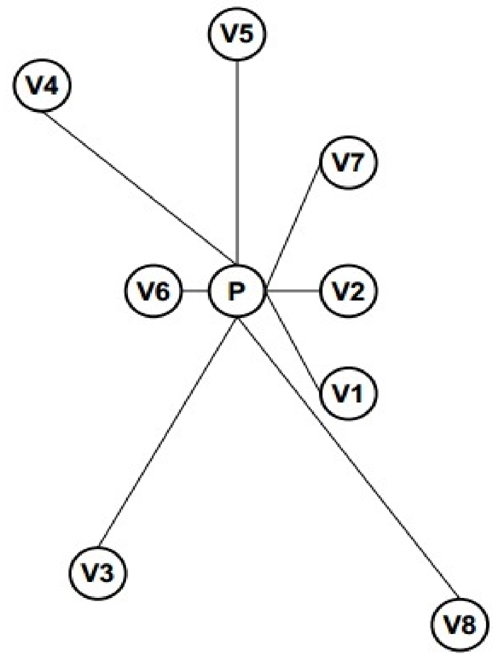

Figure 2. Multi Companies Taxi Environment

3. PROPOSED MODEL

Based on that condition, we propose new collaborative models to give alternative solutions for this problem and this collaborative model becomes the novelty of this research because of many taxi dispatch researches were developed based on non collaborative models. This model is developed based on some justifications. Passenger, vehicle, and company are the stakeholders then their interests must be accommodated. The passenger's interests are waiting time [12], and travel cost. The driver's interests are his revenue, idle time [13-16], and pickup distance. The company's interests are its total revenue and the occupation ratio of its vehicles.

Based on passenger's view, he wants vehicle that offers the lowest travel cost and the lowest waiting time. The lowest travel cost can be achieved from the lowest travel unit cost. The lowest waiting time means the nearest driver to the passenger pickup location. Unfortunately, this situation cannot be provided by one vehicle.

Based on the driver's view, he wants to reduce his idle time and pickup distance, and to increase his revenue. For driver, increasing revenue can be achieved by two ways. The first ways is by increasing the travel unit cost. The second ways is by reducing the idle time. Because the travel unit cost is parameter that confronts between driver and passenger, so in this model, this parameter can be included to the driver's view. So, the parameter that can be included into driver's parameter is idle time. In this model, FIFO with some modifications will be chosen as part of the model.

Based on the company's view, it wants to increases its total revenue and occupation ratio. As it is mentioned above that travel unit cost will confront with passenger's interest, this parameter will not be included into the company's view. So, company can take advantage from its number of vehicles. Increasing number of vehicles will give opportunity to increase the possible total revenue. In the other hand, system also benefits or prefers the company which has higher number of vehicles. In the other hand, company with fewer vehicles still has opportunity to take advantage from this model.

Based on the explanation above, we propose three models. In the first model, we propose the combination between the lowest cost and the longest idle time method. In the second model, we propose the combination between the lowest cost and randomized idle time method. In the third model, we propose the aggregate score of idle time, pickup distance, cost, and fleet size.

In this research, some variables are used to explain the model. Variable v represents the vehicle so that variable V represents the set of the vehicles. Variable c represents the cost. There are some types of cost. Unit cost is the cost per kilometer that is provided by the taxi company and it is represented by c_{unit}. Travel cost is the cost that must be paid by the passenger after uses the travel service for certain travel distance and it is represented by c_{travel}. The c_{travel} formula is explained in Equation 1. There are two types of distance: pickup distance and travel distance. Pickup distance is the distance between passenger pickup location and the vehicle location and it is represented by d_{pickup}. Travel distance is the distance between pickup location and the destination location. It is represented by d_{travel}. These distances are represented in kilometer.

$$c_{travel} = c_{unit} \times \mathrm{int}(d_{travel}) \quad (1)$$

In the first model, the basic concept is system offers the least unit cost and the longest idle time vehicle that is near the passenger. The definition near is actualized by using observation distance (d_{obs}). The observation distance is the maximum distance that the system will find vehicle only if its location is under the observation distance. This concept is similar to the observation range in the previous work [9]. This observation distance is implemented because in driver's perspective, pickup cost should be minimized while in passenger's perspective, waiting time should be minimized too [12].

Process in the first model is divided into several steps. In the first step, system will search vehicles that the pickup distance is lower or equal to the observation distance. Vehicles that meet the requirement then will be joined into vehicle first candidate set or V_{cand1}. This process is described in Equation 2. In Equation 2, variable s_v is the status of the vehicle. The value is 1 if the vehicle is available and the value is 0 if the vehicle is unavailable. The next process is finding the vehicle in the V_{cand1} which has the lowest unit cost. The vehicle that meets the requirement then joins into V_{cand2}. This process is described in Equation 3. The final candidate or the selected vehicle is vehicle in the V_{cand2} that has the lowest idle time (t_{idle}). The idea is that the driver's idle time is the source of taxi inefficiency [13-16]. So, by prioritizing the longer idle time vehicle, the efficiency will be reduced. This process is described in Equation 4. If there is only one vehicle in the V_{cand1} then this vehicle will be the selected vehicle. If there is only one vehicle in the V_{cand2}, then this vehicle will be the selected driver. The algorithm for searching V_{cand1} members is shown in Figure 3.

$$V_{cand1} = \{v \mid d_{pickup} \le d_{obs} \wedge s_v = 1\} \quad (2)$$

$$V_{cand2} = \{v \mid \min(c_{unit}) \wedge v \in V_{cand2}\} \quad (3)$$

$$v_{sel} = v \mid \min(t_{idle}) \wedge v \in V_{cand2} \quad (4)$$

Based on the algorithm in Figure 3, there are several new variables and procedures. Procedure clear is used for emptying the V_{cand1} and V_{cand2} sets. Variable p_p is the passenger position and variable p_v is the vehicle position. Function d() is used for determining the distance between two entities. Function add() is used for adding as a member of a set. Function n() is used for counting the number of a set members. Procedure find_v_{sel}() is used for determining the selected vehicle. The algorithm to determine the selected member is described in Figure 4. In Figure 4, variable lp is used for the buffer that contains the lowest unit cost. Variable idle is used as buffer that contains the highest vehicle idle time.

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```
Begin
 clear(Vcand1)
 clear(Vcand2)
 for i=1 to nv do
 begin
  dpickup ← d(pp,pv)
  if dpickup≤dobs and sv=1 then
    add(Vcand1,vi)
 end
 if n(Vcand1) > 0 then
  find_vsel()
 else
  status ← "fail"
end
```

Figure 3. V_{cand1} Members Searching Algorithm

```
begin
 lp ← cunit(vcand1,1)
 if n(Vcand1) > 1 then
 begin
  for i=2 to n(Vcand1) do
  begin
   if cunit(vcand1,i) > lp then
    lp ← cunit(vcand1,i)
  end
  if n(Vcand1) = 1 then
   vsel ← vcand1,1
  else
  begin
   for i=1 to n(Vcand1) do
   begin
    if cunit(vcand1,i)=lp then
     add(Vcand2,vcand1,i)
   end
   vsel ← vcand2,1
   idle ← tidle(vcand2,1)
   for i=1 to n(Vcand2) do
   begin
    if tidle(vcand2,i)>idle then
    begin
     vsel ← vcand2,i
     idle ← tidle(vcand2,i)
    end
   end
  end
 end
end
```

Figure 4. Vehicle Selection Algorithm

The second model is developed based on the first model. The difference with the first model is that the process in determining the selected vehicle uses stochastic approach. In the second process, Equation 1 and equation 2 is still used. Different to the first model, the selected vehicle is randomized between vehicles in V_{cand2}. The process is described in Equation 5.

$$v_{sel} = random(V_{cand2})) \quad (5)$$

The third model is determined by the summation of the classified variables and it is represented in variable w_{sum}. Each variable is classified into five levels. Variables that are classified includes: d_{pickup}, t_{idle}, c_{unit}, and n_{grveh}. The d_{pickup} variable is accommodated so that the nearer vehicle is more prioritized as nearest driver approach is used in many taxi dispatch system [10-12]. In this model, the n_{gveh} variable represents the number of vehicles in a company. Then, the system searches whether there is vehicle that has maximum value of w_{sum}. After the variables are classified and summed, there is possibility that the value of w_{sum} is equal. These vehicles then are included into V_{cand3}. If the number of vehicles in V_{cand3} is more than one then the selected vehicle is determined randomly. This process is described in Equation 5 to Equation 7. The algorithm is shown in Figure 5.

$$w_{sum} = w(d_{pickup}) + w(d_{idle}) + w(d_{unit}) + w(d_{gv}) \quad (5)$$

$$V_{cand1} = \{v | \max(w_{sum}) \wedge s_v = 1\} \quad (6)$$

$$v_{sel} = random(V_{cand3}) \quad (7)$$

```
begin
 clear(Vcand3)
 bufw ← 0
 for i=0 to nv do
 begin
  w ← calculate_w(vi)
  if w ≥ bufw then
  begin
   add(Vcand3,vi)
   bufw ← w
  end
 end
 vsel ← random(Vcand3)
end
```

Figure 5. The Third Model Algorithm

In this algorithm, some new variables and function are used. Variable bufw is used as buffer for the highest w_{sum} value. Variable w is used for storing the w_{sum} value of the vehicle. Function calculate_w() is used for calculating the w_{sum} score of the vehicle. Function random is used to choose a vehicle among the vehicles in the V_{cand3} set.

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4. IMPLEMENTATION

The proposed model then is implemented into taxi collaboration simulation. In this simulation, vehicles and passengers are generated in a virtual city. The passengers and vehicles have specific location. All passengers make travel order at a same time. Each passenger also has its destination. So, the simulation can be viewed as a dispatch system that will allocate vehicle to execute the order.

In this simulation, the environment is a virtual city. The virtual city represents a medium size city. The size is 15 kilometer in width and 15 kilometer in length. The passengers and vehicles are placed around the city.

Passengers are generated when the simulation begins. When a passenger is generated, all of his parameters are generated too. These parameters are the current location and it will become the pickup location and destination location. These locations are generated randomly and it follows uniform distribution.

Vehicles are also generated when the simulation starts. Similar to passenger, all vehicle parameters are also generated too. These parameters are status, idle time, current location, owner, and the unit cost. The current location is generated randomly and it follows uniform distribution. The idle time is generated randomly and it follows exponential distribution with a certain average value. The owner and the unit cost are generated discretely.

After the simulation session ends, some simulation variables are observed as the simulation result. These variables are financial and non financial variables. These variables are: pickup distance, travel cost, idle time for vehicle that is allocated to the passenger, company's revenue gap.

5. DISCUSSION

After the model is implemented into the simulation application, the collaboration model is then tested to evaluate the performance that the parameters are explained in the previous section. In a simulation session, there are 50 vehicles that are generated. The number of passengers will be generated gradually from 5 persons to 50 persons with the step size is 5 persons. The observation distance is 3 kilometers. So, the purpose is to observe the system performance during the change in the number of passengers.

The tests will be done for five models: three models are the proposed models in this research. The fourth model is the nearest driver model [9]. The fifth model is the longest idle time model [9]. Both the fourth model and the fifth model are the models in the previous work [9]. So, besides comparing between these proposed models, the tests are also as a comparison between this current research and the previous work. The result of the first model is shown in Table 4. The result of the second model is shown in Table 5. The result of the third model is shown in Table 10. The result of the fourth model is shown in Table 11. The result of the fifth model is shown in Table 12.

Table 4. Result of The First Proposed Model

n_p (unit)	d_{pickup} (kilometer)	c_{travel} (rupiah)	t_{idle} (minute)	Pickup ratio (%)	Revenue Gap (rupiah)
5	1.93	24,420	14.9	100	76,600
10	1.97	26,703	17.7	97	123,100
15	1.92	28,683	16.8	97	180,750
20	1.95	29,080	15.5	98	201,150
25	1.87	29,454	16.4	97	224,500
30	1.89	31,005	15.9	94	231,850
35	2.01	32,098	16.4	92	290,500
40	2.04	32,226	17.2	88	206,650
45	2.01	32,680	15.9	87	261,050
50	1.93	31,533	16.2	82	220,750

Based on data in Table 4, it is shown that in the first proposed model, number of passengers affects some parameters but does not affect the other ones. The pickup distance remains fluctuating from 1.87 kilometer to 2.04 kilometer. The travel cost increases significantly when the number of passengers moves from 5 to 30 passengers. After that, the travel cost remains fluctuating with small amplitude. The driver's idle time that the driver gets the order still fluctuates from 14.9 minutes to

17.7 minutes. When the number of passengers increases from 5 to 50 passengers, the pickup ratio falls from 100 percents to 82 percents. The revenue gap between companies rises significantly from 76,600 rupiah to 290,500 rupiah when the number of passengers rises from 5 to 35 passengers. After that, the revenue gap tends to stagnant with small fluctuation.

Table 5: The Result of The Second Proposed Model

n_p (unit)	d_{pickup} (kilometer)	c_{travel} (rupiah)	t_{idle} (minute)	Pickup ratio (%)	Revenue Gap (rupiah)
5	2.01	24,420	10.9	100	76,600
10	2.00	26,708	14	97	123,100
15	1.90	28,665	14.2	97	175,250
20	1.94	29,322	14.3	99	193,600
25	1.88	29,740	15.2	97	225,750
30	1.84	30,998	14.8	94	233,650
35	1.94	32,103	15.7	90	282,050
40	2.03	32,148	16	89	202,400
45	2.01	32,750	15.5	86	252,600
50	1.97	31,442	15.9	82	219,250

Based on data in Table 5, it is shown that in the second proposed model, number of passengers affects some parameters but does not affect the other ones. The pickup distance fluctuates with small amplitude from 1.88 minutes as its lowest value to 2.03 minutes as its highest value. The travel cost increases but not significantly from 24,420 rupiah to 32,103 rupiah when the number of passengers increases from 5 passengers to 35 passengers. After that, the travel cost tends to stagnant with small fluctuation. The increasing of the number of passengers affects the driver's idle time which the driver gets the order but not significant. By ignoring the driver's idle time when the number of passengers is 5 passengers, the driver's idle time increases from 14 minutes to 15.9 minutes with small fluctuation. When the number of passengers increases from 5 passengers to 50 passengers, the pickup ratio falls from 100 percents to 82 percents. The revenue gap increases from 76,600 rupiah to 282,050 rupiah when the number of passengers increases from 5 passengers to 35 passengers. After that, the revenue gap tends to fluctuate.

In the third model, some variables must be classified so that this continuous value of the variable will be transformed into the discrete one. The classification is shown in Table 6 to Table 9. The pickup distance classification is shown in Table 6. The idle time classification is shown in Table 7. The unit cost classification is shown in Table 8. The number of vehicles that is owned by the company is shown in Table 9.

The explanation of Table 6 to table 9 is as follows. In Table 6, longer idle time makes higher score. In Table 7, shorter pickup distance makes higher score. In Table 8, lower unit cost makes higher score. In Table 9, higher number of of vehicles makes higher score. Idle time classification is based on driver's interest because the order will be allocated to the vehicle that has been waiting for longer time. This concept is similar to FIFO. Pickup distance classification is based on both passenger's and driver's interest. Shorter pickup distance means lower passenger's waiting time in one side and lower driver's pickup cost in another side. Unit cost classification is based on passenger's interest so that passenger may get lower travel cost. Number of vehicles classification is based on company's interest because they need to increase their fleet utility and their total revenue.

Table 6: Idle Time Classification

Score	t_{idle} (minutes)
1	$t \leq 1$
2	$1 < t \leq 10$
3	$10 < t \leq 20$
4	$20 < t \leq 30$
5	$t > 30$

Table 7. Pickup Distance Classification

Score	d_{pickup} (kilometer)
1	$d > 2$
2	$1.5 < d \leq 2$
3	$1 < d \leq 1.5$
4	$0.5 < d \leq 1$
5	$d \leq 0.5$

Table 8. Unit Cost Classification

Score	c_{unit} (rupiah)
1	c > 4,500
2	4,000 < c ≤ 4,500
3	3,500 < c ≤ 4,000
4	3,000 < c ≤ 3,500
5	c ≤ 3,000

Table 9. Company's Number of Vehicles Classification

Score	Number of Vehicles
1	n ≤ 25
2	25 < n ≤ 50
3	50 < n ≤ 75
4	75 < n ≤ 100
5	n > 100

Table 10: The Performance of The Third Proposed Model

n_p (unit)	d_{pickup} (kilometer)	c_{travel} (rupiah)	t_{idle} (minute)	Pickup ratio (%)	Revenue Gap (rupiah)
5	7.53	26,480	18.1	100	97,150
10	8.20	29,965	15.8	100	231,300
15	7.82	34,763	18.6	100	404,300
20	7.57	32,258	14.2	100	553,350
25	7.87	32,336	19.7	100	615,350
30	7.97	33,577	14.1	100	728,700
35	8.56	32,513	14.5	100	932,000
40	7.71	34,785	22	100	1,139,800
45	8.15	33,646	15.2	100	1,079,500
50	7.68	33,169	17.2	100	1,273,600

Based on data in Table 10, it is shown that when the system implements third proposed model, the number of passengers affects some parameters and does not affect other ones. The pickup distance fluctuates from 7.53 kilometers to 8.56 kilometers with small amplitude when the the number of passengers increases. The travel cost increases less significant from 26,480 rupiah to 34,763 rupiah when the number of passengers increases from 5 passengers to 15 passengers. After that, the travel cost fluctuates with small amplitude from 32,258 rupiah to 34,785 rupiah. The idle time of the driver who gets the order fluctuates with small amplitude from 14.1 minutes as its lowest value to 22 minutes as its lowest value when the number of passengers increases. The pickup ratio is 100 percents for all number of passengers. The revenue gap increases significantly from 97,150 rupiah to 1,273,600 rupiah when the number of passengers increases from 5 passengers to 50 passengers.

Now, we simulate the system based on the previous models [9]. In the next session, the system implements nearest driver model only or the longest idle time model only. So, other parameters are ignored. The result of nearest driver model is shown in Table 11 while the result of the longest idle time model is shown in Table 12.

Table 11:The Performance of The Nearest Driver Model

n_p (unit)	d_{pickup} (kilometer)	c_{travel} (rupiah)	t_{idle} (minute)	Pickup ratio (%)	Revenue Gap (rupiah)
5	1.27	29,210	16	100	83,000
10	1.29	29,980	13.4	100	100,050
15	1.34	33,233	14.7	100	160,000
20	1.28	32,413	14.2	100	176,050
25	1.32	33,172	14.4	100	246,450
30	1.48	34,590	15.4	100	274,600
35	1.80	34,176	16.2	100	254,700
40	2.00	33,832	16.2	100	208,400
45	2.16	33,530	15.2	100	289,250
50	2.65	32,764	15.4	100	262,750

Based on data in Table 11, it is shown that when system implements full nearest driver model, when the number of passengers increases, some parameters are affected while the others are not. The pickup distance increases from 1.27 kilometers to 2.65 kilometers when the number of passengers increases from 5 passengers to 50 passengers. The

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travel cost tends to fluctuates from 29,210 rupiah to 34,590 rupiah when the number of passengers increases. The idle time of passengers that get the order fluctuates from 13.4 minutes as the lowest value to 16 minutes as the highest value when the number of passengers increases. The pickup ratio is still 100 percents for all number of passengers. The revenue tends to increase with small fluctuation when the number of passengers increases.

Table 12:The Performance of The Longest Idle Time Model

n_p (unit)	d_{pickup} (kilometer)	c_{travel} (rupiah)	t_{idle} (minute)	Pickup ratio (%)	Revenue Gap (rupiah)
5	1.79	34,470	32.2	100	91,250
10	1.99	31,398	26.3	99	96,650
15	1.93	32,675	25.4	97	167,100
20	1.94	34,299	25.1	98	195,650
25	2.02	32,312	20.9	96	200,250
30	1.97	34,725	20.9	93	223,550
35	2.03	34,800	19.5	91	264,350
40	1.91	34,738	18.3	89	257,200
45	1.97	33,606	18.5	84	262,250
50	2.01	33,318	16.6	84	269,250

Based on data in Table 12, it is shown that when system implements longest idle time model, the number of passengers affects some parameters and does not affect the other ones. The pickup distance fluctuates from 1.79 kilometers as the lowest value to 2.03 kilometers as the highest value. The travel cost fluctuates from 31,398 rupiah as the lowest value to 34,800 as the highest value. The idle time falls from 32.2 minutes to 16.6 minutes when the number of passengers increases from 5 passengers to 50 passengers. The pickup ratio falls from 100 percents to 84 percents. The revenue gap increases from 91,250 rupiah to 269,250 rupiah.

Comparing the pickup distance among the models, the full nearest driver model as the previous model performs the best result. The first proposed model, the second proposed model, and the longest idle time model as the previous model performs moderate. The difference between the the nearest driver model and the three models is not significant. The third proposed model performs the worst result among all models and its difference is significant.

Comparing the travel cost among the models, the first and the second proposed models produces the best cost saving. Then, the third proposed model comes next. The longest idle time model produces the worst cost saving. It can be said the longest idle time model is the least efficient in travel cost criteria.

Comparing the idle time among the models, the longest idle time model as previous model performs the best. It means that by using this model, driver with longer idle time is more prioritized. The first proposed model performs better than the second proposed model but it is not significant. The performance of the other models is similar to each other.

Comparing pickup ratio aspects among all models, the third proposed model and the nearest driver model performs the best because as far as the number of the passengers does not outnumbers the number of the vehicles, the pickup ratio is always 100 percents. It is different to the other three models. Because the observation distance is implemented in these three models so there is possibility that there are not any available drivers inside the observation distance.

Comparing the revenue gap aspects, the number of passengers affects the revenue gap. The gap increases very significantly when system implements the third proposed model. In the other side, the increasing of the revenue gap is similar to each other models. So, if we see the equality among companies, the third proposed model is looked unfair. But, if the system pushes the company to have more vehicles for some reasons, the third model gives the best result.

6. CONCLUSION AND FUTURE WORK

Based on the explanation above, it can be seen that the proposed models have been developed and have been implemented into the collaboration taxi simulation. In this research, we have proposed three models. In the first model, order will be allocated to the vehicle that offers the lowest travel cost and has longest idle time in the observation area. In the second model, order will be allocated to the vehicle that offers the lowest travel cost but the model does not guarantee that the longer idle time vehicle will be prioritized. In the third model, the four parameters includes unit cost, vehicle idle time, pickup distance, and the size of the company's fleet will be scored. Then, the order will be allocated to the vehicle which has the highest score.

Linking to the research question and research purpose, especially in performance evaluation, based on the analysis of the simulation result, the three proposed models have answered the research purpose even in some aspects and in the other side, the previous work models which are nearest driver model and longest idle time model still perform better. The first and the second model perform better among the other ones in cost saving aspects. It means that these two proposed model gives lowest travel cost comparing with other models successfully. The third proposed model performs the best in giving incentives for companies which have larger number of vehicles but this model performs the worst in pickup distance aspect. In the other side, as the previous models, the nearest driver model performs the best in offering the lowest pickup distance and the longest idle time model performs the best in offering longer idle time driver to be more prioritized.

Even the third proposed model performs the worst one among the other proposed ones, this model has decisive advantage that as long as at least there is one available vehicle, the order will be picked up. This condition is different to the other ones because in the first and the second models, system searches available vehicle only in its observation area. So, by the increasing of the number of orders, the potential of the order is failed to be picked up is increasing too.

This work is not the end of researches in developing and proposing new or better models in shaping future transportation business. It is because the online based transportation system is still improved. So, better or alternative solutions are still needed so that the future transportation model can benefits all of the stakeholders. Meanwhile, the existing transportation modes still need help in improvement so that these existing modes can compete with the online based ones.

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