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DISTANCE-SCORE COMBINED MODEL IN AUTOMATIC HIGH SCHOOL STUDENT ENROLLMENT SYSTEM

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ABSTRACT

There are some problems in the existing high school student enrollment system in Indonesia. Besides its main goal to create equality in education and student distribution, there are protests from people, especially parents. The new zoning system is blamed because it neglects student national exam score so that there is not any incentive to become smart student. As far as his house is near to the school, student with low national exam score is still prioritized. This policy triggers many families to create fake family certificate. The other policy in accommodating low economy student is also blamed in triggering lots of fake poor family certificate. Based on these real problems, in this paper, we propose new automatic high school student enrollment system. In this work, both home-to-school distance and national exam score are accommodated so that the student is allocated the school that its location is as near as possible from his house. Meanwhile, there is incentive for student who has high national exam score. In this work, we propose four high school student enrollment models. The first model is full round robin total score based model. The second model is semi round robin total score based model. The third model is exam score prioritized-clustered school combined model. The fourth model is exam score prioritized-semi zoning model. These four proposed models then are tested and are compared with the existing models. There are several research findings in this research. The first model produces the best equality in distributing students so that smart students are not concentrated in high quality schools group only. Meanwhile, the first model also produces the lowest home-to-school distance. The second model produces gap among schools with different quality level. By using this model, higher quality schools get benefits in receiving lower average home-to-school distance and students with higher average national exam score. The third model produces significant gap in average national exam score accepted students. Meanwhile, the average home-to-school distance is tended to be higher than the first and second proposed models. The fourth model produces equality in distributing students based on their national exam score when the maximum distance is set moderate. In all models, the number of students does not affect the result.

Keywords: *High School Student Enrollment, National Exam Score, Nearest Distance, Zoning System, Round Robin.*

1. INTRODUCTION

In Indonesia, the new regulation in public high school student enrollment system triggers new problems and polemics in national education stakeholders, especially: school, student, and parent. The unclear socialization from government triggers dispute between school and parents because many students are failed to attend their targeted school [1,2]. The new zoning system triggers many parents to submit fake family certificate. Basically, this fake family certificate is legal because it is issued by the local government. Unfortunately, the written domicile in the certificate is different from the family's real domicile.

The other problem is there are massive fake poor certificates that are issued by the local government during the new student enrollment period [3]. This condition occurs because of the regulation that prioritizing low economy students. In this new regulation, there is minimum quota for school to accept low economy student. Based on this policy, low economy student will be prioritized rather than student with high national exam score. This policy then triggers some parents to make fake poor certificate.

Basically, this new regulation has good missions. The first mission is allocating student to his nearest school. By allocating students to his nearest school, the student travel time will be reduced so that this reduced time can be allocated for other positive activities. By reducing student travel time, the traffic congestion will be reduced too [4,5]. The second goal is creating school equality by reducing performance gap between favorite school and non favorite school [4,5]. It is common that student tends to choose favorite school. So, by using pure national exam score enrollment system, most of favorite school inputs are smart students or students with high national exam score. Meanwhile, most of students with low national exam score. This phenomenon makes the gap between favorite school and non favorite school wider. By using zoning system and ignoring the national exam score, the government hopes that smart students will be distributed equally in all schools and the paradigm about favorite and non favorite schools will be reduced [4]. The problem is that ignoring the national exam score creates perception that there is not any incentive for being smart student.

Basically, zone based model is a common method in student enrollment system in many countries or cities, such as: Portland [7], Alberta [8], Christchurch [9], Chicago [10], ST. Johns [11], New Zealand [12,14], New York [13], and America [14]. The important purposes in implementing zoning system are reducing student transportation time, creating equality among schools, and avoiding certain schools from being overcrowding [9]. Unfortunately, not all students enter the school which its location is in their zone [10]. It is because many parents choose higher performance school [8] and tolerate farther distance so that some parents will send their children to out of zone school if there is not any high performing school in their zone.

These problems then give us motivation to create better high school student enrollment system. Based on these problems, the main research question in this work is what kind of new high school student enrollment system that accommodates distance aspect and national exam score aspect. The secondary research question is how better the proposed model rather than the existing model. So, the research goal is developing new high school student enrollment system that prioritizing the student to enter school as near as possible from his house and still gives incentive for smart student to enter favorite school.

This paper is organized as follows. In the first section, we explain the background, research question, research purpose, and the paper organization. In the second section, we explain the existing zone based high school student enrollment system. In the third section, we describe the proposed model. In the fourth section, we explain the implementation, testing, and discussion about the testing result. In the fifth section, we make conclusion and propose future research potentials.

2. EXISTING DISTANCE BASED HIGH SCHOOL STUDENT ENROLLMENT SYSTEM

In this section, we explain the existing high school student enrollment system in Indonesia. Based on the new regulation, zoning system is implemented so that students apply to school near their home. Besides reducing student travel time, another mission is reducing gap between favorite and non favorite school as it occurs nowadays [4,5]. One condition that is blamed as the reason so that the gap is still wide is because most of smart students will try to enter favorite school. So, by eliminating the student's national exam score, smart students will be distributed equally among all schools. Besides its good mission, there is still problem so that not all students can enter their targeted school. Meanwhile, there are still some empty slots in many schools even the number of students that apply in the enrollment system is higher than the number of allocated slots.

There are two factors that cause this problem. The first factor is that when students make application, they must define his targeted schools manually. In many cases, students have three options [5]. So, the accepted student will enter one of his three schools that are lettered in his submission. Unfortunately, if there is not any school in his list accepts, he will be rejected so that he must apply to the private school to continue his education level. This enrollment model has caused empty slots phenomenon for many years, especially for non favorite school because probability that students put these schools in their list is very low.

The example is as follows. Suppose that there is student s_1 that makes application with three school option $\{c_1, c_2, c_3\}$. Meanwhile, there are 20

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possible schools that can be entered in the high school student enrollment system $\{c_1, c_2, c_3, c_4, \ldots, c_{20}\}$. If at least one of these three schools accepts him then his application is accepted. Unfortunately, if all of these three schools reject his application, his application will be rejected even maybe he is accepted in c_5 or c_8.

The other example is as follows. Suppose that school c_{15} has quota 200 students. Unfortunately, there are only 100 students who put this school in their list. So, if all of these 100 students are accepted in this school then there are still 100 empty slots. Although there are 500 students that are rejected from other schools, these rejected students cannot be transferred to fill the empty slots in c_{15}.

The second factor is the zoning system. In this zoning system, maximum distance policy is applied. This distance is the distance between the school and student's house. So, student which his home-to-school distance is farther than the maximum distance will be rejected to enter the school. This method creates problem for school that the population around it is low even this school is a favorite school.

The example is as follows. Suppose that school c_{18} has zone based quota 150 students. The maximum distance for the zoning system is 2 kilometers. There are 800 students who apply to enter to this school. Unfortunately, there are only 100 students whose house to school distance is equal to or less than 2 kilometers. So, there will be 50 empty chairs in school c_{18}.

Nowadays, there are two main existing distance based models that is used in Indonesia. The first model is pure nearest distance model. The second model is zoning model. This variation occurs because the formal regulation states that public schools must prioritize students whose house is near the school.

In the pure nearest distance model, students will be selected based on his house to school distance (r_{dist}) only. The sorting system is ascending sort. So, student with lower r_{dist} will be prioritized.

In the zoning model, area is divided into several zones based on its distance from the school. The less numbered zone is usually the zone with narrower coverage. The system iterates from the least numbered zone to most numbered zone. The system goes to the next zone only if there are still empty slots after the current zone is proceed. If the number of students in the current zone is higher than the number of available slots then the students with higher national exam score (e) will be prioritized.

The example is as follows. Suppose that school c_{11} has five available chairs. Meanwhile, there are ten students that apply to enter school c_{11}. These students' parameters are shown in Table 1.Suppose that maximum distance (r_{max}) is 2 kilometers.

Table 1. Students Parameters

Driver	r_{dist} (km)	e
s_1	3.2	97
s_2	1.6	86
s_3	0.5	65
s_4	0.2	45
s_5	0.7	77
s_6	1.1	75
s_7	1.4	85
s_8	2.6	99
s_9	1.5	90
s_{10}	0.9	50

Based on data in Table 1, the accepted students list is as follows. Based on pure nearest distance model, the accepted students are $\{s_4, s_3, s_5, s_{10}, s_6\}$. Meanwhile, based on the zone based model, the students that are in the zone are $\{s_2, s_3, s_4, s_5, s_6, s_7, s_9, s_{10}\}$. Because the number of in zone students is higher than the available chairs, national exam score based sorting then is applied. Based on this sorting, the accepted students are $\{s_9, s_2, s_7, s_5, s_6\}$.

3. PROPOSED MODEL

Based on these problems, in this work, we propose automatic student enrollment. It is called automatic because student does not need to define his targeted school. System will distribute the student to the available school automatically. So, as long as the total number of available slots in the system is equal to or higher than the number of students, there is not any student that will be rejected. In this work, both home-to-school distance and national exam score are accommodated.

In this work, there are four proposed models. The first model is full round robin total score based model. The second model is semi round robin total score based model. The third model is national exam score prioritized-clustered school combined model. The fourth model is exam score prioritized-semi zoning model.

In the first model, round robin method is adopted so that there will be equality among schools. The round robin method is a common method that has advantage in balancing the load and this method has been used in our previous work in balancing city courier service load [15]. Basically, the round robin method can be viewed as a rotating wheel. In this rotating wheel, there are schools that its turn is in sequence. When one school gets its turn, it can get one student. The school will get available student with highest total score. After it gets a student then the school after it has turn to get student. The wheel will stop moving after all students have been allocated. In this full round robin model, all school has equal opportunity.

In this first model, student with higher total score will be prioritized to get school earlier. Because the national exam score becomes one part in determining total score, so there is incentive for student with higher national exam score to get school earlier. Meanwhile, because the sequence of the school is like rotating wheel, one of the purposes of this first model is distributing smart students equally to all school. In other side, because the home-to-school is also prioritized, there is incentive for student to enter school that is near him. The full round robin total score based model main algorithm is shown in Figure 1.

In this main algorithm, some new variables are used. Variable n_s denote the number of schools. Variable n_c denotes the number of students. Variable c_{sel} denotes the student that is selected to enter school s_j. Variable $c_{sel,status}$ denotes the status of the selected student: 1 is available and 0 is unavailable. Variable $c_{sel,status}$ denotes the selected student's school. Variable j denotes the current school. Variable $n_{a,j}$ denotes the number of available slots in school s_j.

```
begin
 set(ns)
 set(nc)
 i ← 1
 j ← 1
 while i ≤ nc do
 begin
  if na,j > 0 then
  begin
   csel ← getbeststudent(sj)
   csel,status ← 1
   csel,school ← sj
   na,j ← na,j - 1
  end
  if j < nc
   j ← j + 1
  else
   j ← 1
  i  ← i + 1
 end
end
```

Figure 1. Full Round Robin Total Score Based Model Main Algorithm

In this main algorithm, procedure getbeststudent is used to find the available student with the highest total score relative to the current school (s_j). There are several processes that are run in this procedure. This process is determined by using Equation 1 and Equation 5.

$$c_{sel} = \max(v_{tot}) \wedge c_{status} = 1 \wedge c \in C \quad (1)$$

$$v_{tot,c} = w_{dist}.v_{dist}(c, s_j) + w_e.e_c \quad (2)$$

$$w_{dist} = 1 - w_e \quad (3)$$

$$v_{dist}(c, s_j) = \begin{cases} 100, r_{dist}(c, s_j) \leq 1 \\ \dfrac{100}{r_{dist}(c, s_j)}, else \end{cases} \quad (4)$$

$$r_{dist}(c, s_j) = \| c - s_j \| \quad (5)$$

The explanation of these Equations is as follows. In Equation 1, the selected student is the available student with the highest total score (v_{tot}). In Equation 2, the total score is the summation of weighted distance score (v_{dist}) and weighted national exam score (e). In Equation 2, variable w_{dist} denotes the weight of distance score and variable w_e denotes the weight of national exam score. In Equation 3, it is shown that both weight variables are floating point with their value is less than 1 and the summation of both variables is equal to 1. It means that when the distance weight increases, the national exam score weight decreases and vice versa. In Equation 4, higher home-to-school distance (r_{dist}) will make the distance score lower. Meanwhile, if the distance is less than or equal to 1 kilometer, the distance score is 100. In equation 5, the home-to-school distance is the Euclidean distance between the student's home and the referred school (s_j).

The second model is semi round robin score based model. In this model, schools in the system are clustered into some groups. The group denotes the school quality. For example, there are three groups: high, medium, and low. So, high quality school will be clustered into high. In this model, round robin runs inside the group only. Meanwhile, the turning process among groups occurs sequentially based on the quality where higher quality group will be prioritized rather than lower quality one. By using this model, there is incentive for being high quality school. In other side, there is also incentive for student with higher total score to enter higher quality school. The main algorithm of the semi round robin total score based model is shown in Figure 2.

```
begin
 set(nc)
 nac ← nc
 set(ng)
 i ← 1
 j ← 1
 k ← 1
 status ← "run"
 while status = "run" do
 begin
  csel ← getbeststudent(sj,k)
  csel,status ← 0
  csel,school ← sj,k
  na,j,k ← na,j,k - 1
  nac ← nac - 1
  if nac > 0 then
   setnextschool()
  else
   status ← "stop"
 end
end
```

Figure 2. Semi Round Robin Total Score Based Model Main Algorithm

In this main algorithm, some new variables are used. Variable n_{ac} denotes the number of available students or number of students that have been allocated. In the beginning, the n_{ac} value is n_c. Variable n_g denotes the number of groups. Variable k denotes group index. Variable status denotes the status of the enrollment process. It is shown that the process still continues as long as its status is run. The student finding process in the second model is similar to the student finding process in the first model that uses Equation 1 to Equation 5.

After the current school has got new student and the n_{ac} value is still more than 0, the next process is finding the next school to get its new student. This process is done by executing the setnextschool procedure. This procedure algorithm is shown in Figure 3.

```
begin
 //search in the same group
 found ← false
 search ← "run"
 if j < ns,k
  j ← j + 1
 else
  j ← 1
 t ← 1
 while search = "run" do
 begin
  if na,j,k > 0 then
  begin
   found ← true
   search ← "stop"
  end
  else
  begin
   t ← t + 1
   if j < ns,k
    j ← j + 1
   else
    j ← 1
   if t > ns,k then
    search ← "stop"
  end
 end
 if found = false then
  gotonextgroup(k)
end
```

Figure 3. Algorithm for Finding Next School in Second Proposed Model

The explanation of algorithm in Figure 3 is as follows. The main process is finding the next available school or school that still has empty chairs. This process is done by running round robin process inside the group. This process will stop if the available school is found or there is not any available school anymore in this group. If there is not any available school in this group then the process is continued to go to next group. This process is done by executing the gotonextgroup procedure. This gotonextgroup procedure algorithm is shown in Figure 4.

```
Begin
 if k < ng then
 begin
  k ← k + 1
  j ← 1
 end
 else
  status ← "stop"
end
```

Figure 4. Go to Next Group Algorithm

The explanation of algorithm in Figure 4 is as follows. If the group index is still less than the number of group then the group index increments and it denotes that the turn goes to next group. If this condition occurs, the school index is set to 1. Otherwise, the enrollment status will be stop which means that there is not any available school anymore.

In the third model, student with higher national exam score will be prioritized to get school earlier rather than the student with lower national exam score. Besides this incentive, student with higher national exam score will be prioritized to enter school with higher quality. It is done by searching the available school gradually from the higher quality school to the lower quality school. If there is more than one school in the same group that is available then the student will enter the nearest school one. The main algorithm of this third model is shown in Figure 5.

```
begin
 set(nc)
 nas ← ns
 nac ← nc
 status ← "run"
 while status = "run" do
 begin
  csel ← getnextstudent()
  csel,school ← findschool(csel)
  csel,status ← 0
  nac ← nac - 1
  if nac = 0 or nas = 0 then
   status = "stop"
 end
end
```

Figure 5. National Exam Score Prioritized-clustered School Combined Model

There are some new variables in the algorithm in Figure 5. Variable n_{as} denotes the number of available schools. In this algorithm, the selected student to get school is determined by using the getnextschool procedure. This process is determined by using Equation 6. The school finding procedure in certain group is determined by using Equation 7. Meanwhile, the algorithm to find the school is shown in Figure 6.

$$c_{sel} = \max(e) \wedge c_{status} = 1 \wedge c \in C \quad (6)$$

$$s_{sel} = \min(r_{dist}(s, c_{sel})) \wedge n_{as,s} > 0 \wedge s \in G_k \quad (7)$$

```
begin
 k ← 1
 search ← "run"
 while search = "run" do
 begin
  found ← findavailable(k)
  if found ← true then
  begin
   j ← getbestschool(k)
   na,j ← na,j - 1
   search ← "stop"
   if na,j = 0 then
    nas ← nas - 1
  end
  if k < ng then
   k ← k + 1
 end
end
```

Figure 6. Algorithm of the Finding School Procedure of The Third Proposed Model

The explanation of these equations is as follows. In Equation 6, it is shown that the selected student that his status is still available and gets the highest national exam score. In Equation 7, it is shown that the selected school is available school in the group which its location is the nearest to the student's house.

The explanation of the algorithm in Figure 6 is as follows. The main process is searching available school from the smallest indexed group to the biggest indexed group. But, if the available school has been found in the current group, the iteration will stop. If there is available school in the current group then the school selecting process is done by running the getbestschool function. This function result is determined by using Equation 7.

The fourth proposed model is the combination of the third proposed model with the pure nearest distance model. Similar to the third model, the student with higher national exam score will be prioritized to get school earlier rather than the student with lower national exam score. In this

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model, the maximum distance is applied. The main algorithm of this fourth proposd model is shown in Figure 7.

```
begin
 set(nc)
 nas ← ns
 nac ← nc
 status ← "run"
 while status = "run" do
 begin
  csel ← getnextstudent()
  found ← findinrange(csel,rmax)
  if found = true then
   csel,school ← findschool(csel)
  else
   csel,school ← findnearest(csel)
  csel,status ← 0
  nac ← nac - 1
  if nac = 0 or nas = 0 then
   status = "stop"
 end
end
```

Figure 7. National Exam Score Prioritized-Semi Zoning Model

As it is shown in Figure 7, most of these processes are similar to the processes in the third proposed model. The difference is after the selected student is determined, there is function to detect whether there is at least one available school inside the student's zone. If the function result is true than the findingschool function in Figure 5 is done with improvisation that the schools that are involved are school within the zone. Otherwise, the selected school is the available school that its location is the nearest to the student's home and the school quality is ignored.

4. IMPLEMENTATION AND DISCUSSION

These four proposed models then will be implemented into high school student enrollment simulation application. This simulation application is developed as a web based application and by using PHP language. This simulation is used to evaluate the performance of the model in allocating new student application to the appropriate school.

The simulation scenario is as follows. The environment is a virtual square city which its size is 20 kilometers length and 20 kilometers width. There are 10 high schools in this city that are clustered into three groups based on its quality. There are three high quality schools, four medium quality schools, and three low quality schools. The student allocation is same for all schools. At the beginning, the location of these schools is generated randomly inside the city which it follows uniform distribution. At the beginning, total number of available slots is equal to the total number of students.

Besides the schools, students are also generated before automatic enrollment process runs. The number of students ranges from 500 to 1,500 students. The student's home location and his national exam score are also generated randomly and they follow uniform distribution. The student's national exam score ranges from 40 to 100.

In these tests, there are adjusted and observed variables. The adjusted variable is the number of students. The observed variables are average student home-to-school distance and the observed school group variables. The observed schools variables are the average student's home-to-school distance and national exam score who enter these school groups.

In the first test, the first proposed model is tested. In this test, there are three cases based on the national exam weight: 0.25, 0.5, and 0.75. In each case, the number of student ranges from 500 to 1,500 students with step size is 100 students. There are five simulation sessions in every step. The result is shown in Table 2, Table 3, and Table 4.

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Table 2. Test Result of the Full Round Robin Total Score Model By Using 0.25 National Exam Score Weight

n_s (person)	Succes Ratio (%)	Average r_{dist} (km)	High Quality School		Medium Quality School		Low Quality School	
			Average r_{dist} (km)	Average e	Average r_{dist} (km)	Average e	Average r_{dist} (km)	Average e
500	100	5.4	4.4	68.2	5.2	69.8	6.2	71.6
600	100	4.4	4.4	70.4	4.2	68.6	4.4	70.6
700	100	5.2	4.8	71.8	4.8	70.2	4.4	69.6
800	100	4.8	5.2	70.8	4.8	68.6	4.8	71.4
900	100	4.6	4.6	70.4	5	70.4	4.2	68.4
1000	100	4.6	4.4	69.8	4.6	69.6	5.6	71.2
1100	100	5	5.4	72.2	4.6	68.8	4	69
1200	100	5.2	3.8	68.8	5.4	71.4	5.6	70
1300	100	4.8	4.8	69.6	4.4	70.8	4.8	70.6
1400	100	4.8	5.2	70.2	5	70.2	4.2	69.4
1500	100	4.6	4.4	69.8	5	71.2	4.6	69.4

Table 3. Test Result of the Full Round Robin Total Score Model By Using 0.5 National Exam Score Weight

n_s (person)	Succes Ratio (%)	Average r_{dist} (km)	High Quality School		Medium Quality School		Low Quality School	
			Average r_{dist} (km)	Average e	Average r_{dist} (km)	Average e	Average r_{dist} (km)	Average e
500	100	5.2	4	69.2	5.4	69.4	7	70.4
600	100	5.2	5	70.4	5.2	69.4	5.8	70
700	100	3.8	4	71	3.6	69.8	4.4	70.6
800	100	5.4	5.8	69.6	5.4	70.2	4.8	68.2
900	100	4.4	4.2	69.8	4.2	70	4.6	69.2
1000	100	4.2	4.2	71.2	4.6	70	3.8	70
1100	100	5.2	5.2	70.2	4.4	69.4	5.6	70.2
1200	100	5.2	4.8	70.2	5.6	71	5.4	69.6
1300	100	4.4	4.6	70	4.4	70.4	4	69.6
1400	100	4.4	4.8	70.4	3.8	70	3.8	69
1500	100	4.6	5	70.6	4.4	69.4	4.2	70.6

Table 4. Test Result of the Full Round Robin Total Score Model By Using 0.75 National Exam Score Weight

n_s (person)	Succes Ratio (%)	Average r_{dist} (km)	High Quality School		Medium Quality School		Low Quality School	
			Average r_{dist} (km)	Average e	Average r_{dist} (km)	Average e	Average r_{dist} (km)	Average e
500	100	4.8	4.4	70.2	4.2	69.8	5.6	70.0
600	100	5.2	5.8	70.4	5.0	69.4	5.2	69.0
700	100	4.4	4.0	70.2	5.0	70.2	4.2	69.6
800	100	5.6	6.0	70.4	5.2	69.2	5.4	69.8
900	100	5.0	4.4	69.6	4.6	70.0	5.6	70.0
1000	100	4.8	5.0	70.8	4.6	69.8	4.0	69.6
1100	100	5.2	4.6	70.0	5.2	70.2	5.4	70.4
1200	100	5.0	4.4	70.0	5.4	70.2	5.2	70.2
1300	100	5.2	5.6	70.0	4.8	70.2	5.6	70.2
1400	100	4.0	4.0	70.0	4.0	70.3	4.2	70.3
1500	100	4.4	4.2	70.6	4.6	69.8	4.6	70.2

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Based on data in Table 2, Table 3, and Table 4, it is shown that by using the first model, there is equality in average national exam score and home-to-school distance. Generally, the average home-to-school distance ranges from four kilometers to seven kilometers. Most of average home-to-school distances are 4 and 5 kilometers. This condition occurs in all school groups. Meanwhile, the average national exam score ranges from 60 to 70. This condition also occurs in all school groups. Based on this result, it can be said that by implementing the first model, the system guarantees the full equality in national exam score and home-to-school distance among all schools and there is not any gap among school groups.

In this first model, the number of students and weight variables do not affect the result. It is shown that there is not any difference among different weight as it is compared from data in Table 2, Table 3, and Table 4.. It is also shown that when there is not any change in the number of schools, change in number of students does not change the observed variables as long as the total number of slots is still higher than or equal to the number of students or applicants. It is also shown that by using this model, all scenario results 100 percents success ratio which means that there is not any unallocated student.

In the second test, the second proposed model is tested. In this test, there are three cases based on the national exam weight: 0.25, 0.5, and 0.75. In each case, the number of student ranges from 500 to 1,500 students with step size is 100 students. There are five simulation sessions in every step. The result is shown in Table 5, Table 6, and Table 7.

Table 5. Test Result of the Semi Round Robin Total Score Model by Using 0.25 National Exam Score Weight

n_s (person)	Succes Ratio (%)	Average r_{dist} (km)	High Quality School		Medium Quality School		Low Quality School	
			Average r_{dist} (km)	Average e	Average r_{dist} (km)	Average e	Average r_{dist} (km)	Average e
500	100	5.4	3.4	77	5	73.6	8.2	58.2
600	100	5.8	3	75.6	5.4	75	9	59
700	100	5.2	2.8	75.8	5.2	73.2	7.6	58.8
800	100	5.4	3.4	77	4.8	72.6	8.4	57.8
900	100	5.4	3	76	5.8	74.6	7.2	58.2
1000	100	5.2	3	76	5	73.8	8.4	58.2
1100	100	4.8	3	76.4	4.8	73.6	7	59
1200	100	4.6	3	76.6	4.2	74	6.8	59
1300	100	5.2	3	76.8	4.6	74	8	58.8
1400	100	5.2	3.2	76.6	4.8	73.6	8	58.2
1500	100	6	3.6	76.2	5.4	73.8	9	57.4

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Table 6. Test Result of the Semi Round Robin Total Score Model by Using 0.5 National Exam Score Weight

n_s (person)	Succes Ratio (%)	Average r_{dist} (km)	High Quality School		Medium Quality School		Low Quality School	
			Average r_{dist} (km)	Average e	Average r_{dist} (km)	Average e	Average r_{dist} (km)	Average e
500	100	5.6	4.4	85	5	72.6	7.8	51.4
600	100	5.6	4	86	5.4	71.4	7.4	53
700	100	5	4.6	84.6	4.8	72	6.6	52.2
800	100	6.8	4.8	85.6	6.2	71.6	8.8	52.2
900	100	6.2	4.4	85	5.4	72.6	8.6	52.8
1000	100	6.2	4.2	85.6	6.2	70.8	7.4	52
1100	100	5.6	4.6	84.8	5.6	72.2	6.8	53
1200	100	5.6	4.8	85	4.4	71.4	8	52.6
1300	100	5.4	5.4	85.2	4.6	71.4	7	53.2
1400	100	6	4.6	85.4	5.4	72.2	7.6	53
1500	100	5.6	4.2	85.2	5.6	71.8	7.6	52.8

Table 7. Test Result of the Semi Round Robin Total Score Model by Using 0.75 National Exam Score Weight

n_s (person)	Succes Ratio (%)	Average r_{dist} (km)	High Quality School		Medium Quality School		Low Quality School	
			Average r_{dist} (km)	Average e	Average r_{dist} (km)	Average e	Average r_{dist} (km)	Average e
500	100	6.4	6.6	90.6	5.8	70.4	6.6	49.6
600	100	6.6	6.6	90.4	5.4	70.2	7.4	49.8
700	100	7	7.4	90.2	6.4	69.8	7.8	49.8
800	100	6.2	5.4	90.2	5.8	69.8	7.6	49.6
900	100	6.4	6	90.4	6.8	69.6	7	49.8
1000	100	6	5.6	90.2	5.6	70.2	7.4	49.8
1100	100	6.4	6.8	90.4	5.8	69.8	7	50
1200	100	6.4	5.4	90.2	6.6	70.6	7.8	49.6
1300	100	6.2	6.4	90.6	5.8	70.4	7	50
1400	100	6.4	6.8	90.4	4.8	69.8	7.6	49.4
1500	100	6.8	6.8	89.8	6.2	69.4	7.8	49.2

Based on data in Table 5, table 6, and Table 7, it is shown that when the enrollment system adopts the second proposed model, the equality among school groups has been reduced. This condition occurs both in average home-to-school distance and average national exam score.

Based on the home-to-school distance, it is shown that when the distance weight is higher, the distance gap between school groups is wider. School in higher group tends to accept nearer home-to-school distance rather than school in lower group. In this case, there is not any significant difference among average national exam score. It is shown in Table 5.

When the national exam score weight is higher, the exam score makes the average national exam score gap among school groups wider. Schools with higher quality tend to accept students with higher national exam score rather than schools with lower quality as it is shown in Table 7. In this case, there is not any significant difference among average home-to-school distance among school groups. When the national exam score weight increases, school group ignored average home-to-school distance also increases even the increasing trend is not high.

Similar to the first model, there is not any difference in results when the number of students increases as long as the number of schools does not

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change. Meanwhile, as long as the total number of slots is higher than or equal to total number of students, all students are allocated. It is shown that in all cases, the success ratio is 100 percents.

In the third test, the third proposed model is tested. In each case, the number of student ranges from 500 to 1,500 students with step size is 100 students. There are five simulation sessions in every step. The result is shown in Table 8.

Table 8. Test Result of the National Exam Score Prioritized-Clustered School Combined Model

n_s (person)	Succes Ratio (%)	Average r_{dist} (km)	High Quality School		Medium Quality School		Low Quality School	
			Average r_{dist} (km)	Average e	Average r_{dist} (km)	Average e	Average r_{dist} (km)	Average e
500	100	7.6	8.8	91.4	6.6	70.4	7.8	49
600	100	7.4	7.2	90.8	8	69.6	7.4	48.8
700	100	7	8	91.4	6.6	69.6	7.2	48.8
800	100	7.6	7.8	91.2	7.8	70.2	7.2	48.8
900	100	7	7.8	91.2	6.2	70.4	7.4	48.8
1000	100	7.2	6.8	91.6	7.4	70.4	7.4	48.8
1100	100	7.6	8	91	6.4	69.6	8	48.8
1200	100	7.6	8.4	91.6	7.2	70.2	7.6	48.8
1300	100	7	7.8	91.2	6.8	70.2	6.8	48.6
1400	100	6.8	7.4	91.2	6.4	70	7	48.2
1500	100	7	7.4	91	6.6	69.8	6.8	48.8

Based on data in Table 8, it is shown that it is shown that the third model creates gap in average national exam score among school groups. Meanwhile, there is not any significant difference in average student's home-to-school distance among school groups. By comparing the average national exam score in every group, it is shown that higher quality school will get students with higher average national score. Meanwhile, schools with lower quality level will get lower average national exam score students. This gap is very significant.

In the other side, there is no difference in average home-to-school distance among groups. This condition is shown in column 3, 4, 6, and 8 which the home-to-school distance ranges from 6 to 7 kilometers generally.

In this model, the number of students does not affect the result. As it is shown in Table 8, there is not any difference in result when the number of students increases. Meanwhile, the success ratio is 100 percents for all number of students.

In the fourth test, the fourth proposed model is tested. In this test, there are three cases based on the maximum distance: 2.5 kilometers, 5 kilometers, and 7.5 kilometers. In each case, the number of student ranges from 500 to 1,500 students with step size is 100 students. There are five simulation sessions in every step. The result is shown in Table 9, Table 10, and Table 11.

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Table 9. Test Result of the Exam Score Prioritized-Semi Zoning Model By Using 2.5 Kilometers Maximum Distance

n_s (person)	Succes Ratio (%)	Average r_{dist} (km)	High Quality School		Medium Quality School		Low Quality School	
			Average r_{dist} (km)	Average e	Average r_{dist} (km)	Average e	Average r_{dist} (km)	Average e
500	100	8.6	7.2	56.2	8.4	67.2	10.4	87.4
600	100	8.6	6.8	56.4	8.6	67.4	10.8	87.0
700	100	8.6	7.4	55.6	9.0	66.8	9.2	88.0
800	100	8.5	6.7	56.5	8.8	66.5	10.0	87.5
900	100	8.7	7.2	56.5	8.8	67.2	10.3	87.5
1000	100	9.0	7.2	55.4	8.8	67.8	10.2	88.4
1100	100	8.6	7.8	55.6	8.4	66.8	10.4	87.2
1200	100	9.0	7.8	55.6	9.0	67.6	9.8	88.4
1300	100	8.8	7.4	56.0	8.4	67.4	11.4	87.4
1400	100	8.6	7.6	55.6	9.2	67.2	9.8	88.2
1500	100	8.8	7.4	56.0	8.4	67.2	10.8	87.6

Table 10. Test Result of the Exam Score Prioritized-Semi Zoning Model By Using 5 Kilometers Maximum Distance

n_s (person)	Succes Ratio (%)	Average r_{dist} (km)	High Quality School		Medium Quality School		Low Quality School	
			Average r_{dist} (km)	Average e	Average r_{dist} (km)	Average e	Average r_{dist} (km)	Average e
500	100	6.6	4.6	73.0	5.4	64.0	10.0	73.0
600	100	7.4	4.0	72.6	6.8	64.4	11.4	74.2
700	100	7.0	3.5	76.3	5.8	63.5	10.8	73.0
800	100	6.2	3.4	77.8	4.8	64.8	10.2	69.6
900	100	6.5	4.0	74.0	5.5	64.5	10.8	71.3
1000	100	6.6	3.4	78.4	5.8	62.8	10.8	72.2
1100	100	6.2	3.2	73.2	5.0	66.8	9.6	70.4
1200	100	6.3	3.0	76.8	6.8	62.3	8.8	74.5
1300	100	6.4	3.4	74.8	6.0	64.4	10.0	72.4
1400	100	6.2	3.4	75.0	6.2	63.4	9.2	73.0
1500	100	5.5	3.8	74.3	4.8	65.5	8.3	71.0

Table 11. Test Result of the Exam Score Prioritized-Semi Zoning Model By Using 7.5 Kilometers Maximum Distance

n_s (person)	Succes Ratio (%)	Average r_{dist} (km)	High Quality School		Medium Quality School		Low Quality School	
			Average r_{dist} (km)	Average e	Average r_{dist} (km)	Average e	Average r_{dist} (km)	Average e
500	100	6.4	4.2	84.6	5.4	64.6	9.4	62.4
600	100	5.8	4.2	86.0	4.6	66.2	9.2	60.4
700	100	6.8	4.0	84.6	6.4	61.6	10.0	66.0
800	100	6.4	4.8	87.2	5.0	65.8	10.0	59.0
900	100	5.6	4.8	85.6	4.2	69.4	8.8	54.4
1000	100	5.6	4.4	86.0	4.6	69.2	7.8	53.8
1100	100	5.7	4.2	83.7	5.0	68.0	8.5	59.2
1200	100	6.2	4.2	82.6	5.8	65.4	8.2	63.4
1300	100	6.2	4.4	85.6	6.0	65.2	9.2	61.6
1400	100	5.8	4.4	85.6	4.2	70.2	9.4	55.0
1500	100	6.2	4.0	83.2	4.8	68.6	10.0	58.8

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Based on data in Table 9 to Table 11, it is shown that there is distribution difference in average national exam score when the maximum distance changes. As it is shown in Table 9, when the maximum distance is low, schools with higher quality receive students with lower average national exam score. Meanwhile, schools with lower quality receive students with higher average national exam score. As it is shown in Table 10, when the maximum distance is moderate, schools with higher and lower quality receive students with higher national exam score. Meanwhile, schools with medium quality receive students with lower national exam score. But, the gap among them is not significant. As it is shown in Table 11, when the maximum distance is high, schools with higher quality receive students with higher average national exam score. Meanwhile, schools with lower quality receive students with lower average lower national exam score. Based on this explanation, equality in distributing smart students will be achieved when the maximum distance is set moderate.

The distribution of average home-to-school distance is as follows. When the maximum distance is low, the average home-to-school distance is very high. Meanwhile, the increasing of the maximum distance makes the average home-to-school distance decrease. In the same distance level, schools with higher quality level receive students with lower average home-to-school distance. Meanwhile, schools with lower quality level receive students with higher average home-to-school distance.

The next observation is evaluating the student’s average home-to-school distance among models and cases. The result is shown In Figure 8. Based on data in Figure 8, it is shown that when the system implements the fourth proposed model with low maximum distance, the average home-to-school distance is high. This gap is far enough when it is compared with other proposed models. Meanwhile, the first model produces low average home-to-school distance in all weight values. Other models produce moderate average home-to-school distance. Data in Figure 8 strengthens the statement that number of students does not affect the average home-to-school distance.

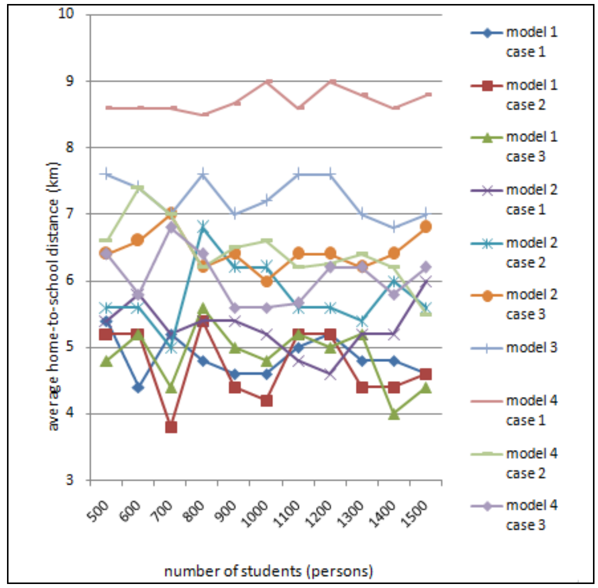

Figure 8. Average Home-to-school Distance Comparison among Models

There are limitations in this work besides its findings and contributions. The academic performance that is used in this work is the student’s academic score only. Meanwhile, in other case, student’s academic report is also concerned in academic performance. In many cases in the real world, the student’s achievement in sport and art activities are also included to increase the total academic score. Nowadays, each local government has its won policy in conversing the student’s sport and art activities into academic performance score.

The other limitation is that the low financial aspect is excluded. Based on the policy that has been issued by the central government, school may not reject students with low financial capacity. Unfortunately, there are some disputes when the local governments interpret this policy. Some local government put the low financial aspect as the highest prioritize. Other governments still prioritize the distance and academic performance aspects above the low financial aspect. That is why the low financial aspect is excluded in this work.

In this work, the model is evaluated in the fixed size area with fixed number of schools and single schools’ and students’ location distribution. So, it is important to evaluate these models’ performance in various area sizes, number of schools and student’s and schools’ location distribution. It is because in the real world, the schools and students location is not distributed uniformly. In some cities, students’ home location is centralized in the city central while in other cities, the students' home location is spread in the suburbs. Meanwhile, in many cities, lots of high schools are founded in the city central and few high schools are in the suburbs.

Compared with other work [16], the performance of these models is as follows. As an automatic system, the performance in success ratio of these four proposed models is same with the zone based school enrollment model that uses k-means clustering [16]. Meanwhile, the success ratio of these four models is higher than the existing static method [16]. In student's home to school distance aspect, some of these proposed models perform as competitive as the existing static method does [16]. Meanwhile, other proposed models perform less competitive than the existing static model does [16].

5. CONCLUSION AND FUTURE WORK

Based on the explanation above, there are four proposed models and they have been implemented into high school student enrollment simulation application. These four models are developed in accordance to solve the main problem in the existing high school student enrollment system in Indonesia that is processed manually. Although the total number of slots is higher than or equal to the number of applicants, there is potential where some students are rejected to enter their targeted schools. Based on the test results, it is shown that by using these four models, all students have been allocated successfully. The other concerns are reducing the home-to-school distance, appreciating student academic performance, and reducing gap between favorite and non favorite schools. With different proportions, these four models also have accommodated these explained concerns.

There are several research findings in this work. The first model produces the best equality in distributing students so that smart students are not concentrated in high quality schools group only. Meanwhile, the first model also produces the lowest home-to-school distance. The second model produces gap among schools with different quality level. By using this model, higher quality schools get benefits in receiving lower average home-to-school distance and students with higher average national exam score. The third model produces significant gap in average national exam score accepted students. Meanwhile, the average home-to-school distance is tended to be higher than the first and second proposed models. The fourth model produces equality in distributing students based on their national exam score when the maximum distance is set moderate. The number of students does not affect the result.

There are several research potentials in developing and especially implementing automatic student enrollment system. As applied based research, many student enrollment systems that use real field data must be done to evaluate the model performance in the real condition. In other side, implementing these new enrollment models in the real condition is very important to evaluate whether these models must be improved or be adjusted to get best result.

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