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Ant Colony Optimization (ACO) for Short Route Calculation

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Abstract:- This study was anchored on the development of a Mobile Application that would determine the shortest route and to provide an ideal solution with short path route calculations using a more well-matched and complex algorithm, some modern techniques, and diverse variants of problems in VRPs. Other objectives include, to test the efficiency of Ant Colony Optimization (ACO) Algorithm and test the software quality characteristic of the developed application in terms of the different characteristics based on the ISO 25010.

In achieving these objectives, the researcher gathered relevant information, through interviews, searching for Internet articles as well as existing applications which are similar to the application. Questionnaires were prepared and collected from the participants during initial development and final testing. Based on the results accumulated which can be found on the tables presented, it proved that the researcher's objectives of the study were meet.

Keywords:- *Shortest Route, Ant Colony Optimization, Endpoints, Quality Best Route, Vehicle Routing Problem*

I. INTRODUCTION

Public transportation provides commuters with a convenient method to reach their destination faster and cheaper compared with private vehicles. Transferring people to their places of work, homes, and as well the other destinations. While public transport can be used first for commercial purposes moving people to diverse locations, this service can also be in form of courier baggage and others.

Considering the growth of mobile Internet technology, the user's travel information is becoming more and more diversified. Travel notes, strategies, short videos, and so on have become the leading basis for the user route planning (M Salehi Sarbijan, 2022).

As transportation in the Philippines is relatively unfledged, maybe due to the country's mountainous areas and scattered islands, and partly as a result of the government's persistent under investment in the nation's infrastructure. In recent years, the Philippine government has been pushing to improve the transportation system in the country through various projects.

In the rural area context, many distribution companies service their customers with non-homogeneous fleets of trucks, cars and vans. However, most common problems arise from routes. And finding a set of routes minimizing the number of travelled kilometers and the number of used vehicles, while satisfying customer demand is the main focus or center (DOTR, 2022).

The mentioned concern above is identified as one of the Vehicle Routing Problem (VRP) in the business logistics. This VRP is one of the most significant subjects for logistic activities. The time which the vehicle travels from point A to B is certain in all the VRP model and the VRP variants model, but in fact the time spent on the road from point A to B is usually not a constant value in actual life because of dynamic road congestion, different fatigue degrees of driver and the vehicle condition etc. (Sadman Rahman, 2020).

Moreover, many distribution companies service their customers with fleets of trucks. Their problem is to find a set of routes minimizing the number of travelled kilometers and the number of used vehicles, while satisfying customer demand. There are three major problems why traditional Operations Research techniques are not enough to deal with this problem, which is known as the Vehicle Routing Problem.

The main purpose of Vehicle Routing Problem (VRP) is to get the least cost routes for fleet vehicles departing from one point to a set of service points (Help Scout, 2022). As tested and proposed by many studies such as different optimizations, aimed to a single purpose – to provide an ideal solution which is short path route calculations using a more compatible and complex algorithm, several modern techniques different variants of problems in VRPs. These include Ant Colony Algorithm (ACO).

- ➢ *Objectives of the Study*
- *General Objective:*

The general objective of the study was to develop a Mobile application that would determine the shortest route integrated with Ant Colony Optimization (ACO) Algorithm.

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- *Specific Objectives:*
  Specifically, this study sought to:

✓ design and develop a Mobile Application integrated with Ant Colony Optimization (ACO) Algorithm for short path calculation;
✓ determine the efficiency of the developed mobile application using the Test of Quality Best Route of Ant Colony Optimization, and;
✓ test the software quality characteristics of the developed application based on ISO 25010 standards.

➢ *Framework of the Study*

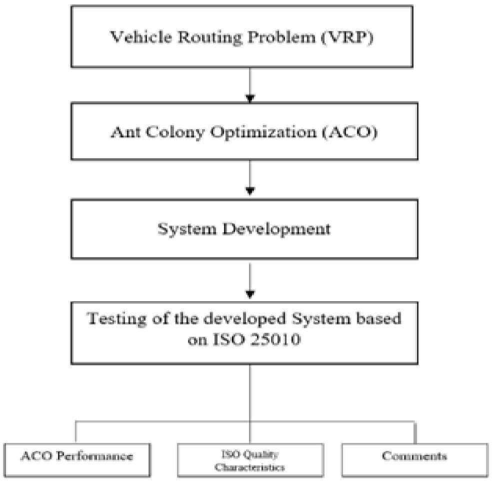

Fig 1:- The Conceptual Framework of the Study.

This framework gives a graphical representation on the conceptual structure of the study. It identifies what are the possible input materials and information that are needed, the process that interconnects from the processed data which transformed into useful information, the output which in all showcasing the comprehensive road map of the conduct of the study.

II. METHODOLOGY

➢ *Research Design*

The researcher adopted the developmental type of research to achieve the purpose of the study. This method is a fact-finding study that encompasses sufficient and precise interpretation of data and their findings. This approach is appropriate wherever the object of a class varies among themselves and one is interested in knowing the extent to which different conditions obtain among objects. The data from a descriptive survey were used as basis that may aid in solving practical complications.

➢ *The Software Development Life Cycle (SDLC)*

It is a process that produces software with the highest superiority and lowest cost in the shortest time. SDLC includes a detailed plan for how to develop, alter, maintain, and replace a software system. It involves several distinct stages, including planning, design, building, testing, and deployment. Popular SDLC models include the waterfall model, spiral model, and Agile model.

SDLC works by lowering the cost of software development while simultaneously improving quality and shortening production time. SDLC achieves these apparently divergent goals by following a plan that removes the typical pitfalls to software development projects. That plan starts by evaluating existing systems for deficiencies. Next, it defines the requirements of the new system. It then creates the software through the stages of design, development, testing, and deployment. By anticipating costly mistakes like failing to ask the end user for suggestions, SLDC can eliminate redundant rework and after-the-fact fixes.

➢ *Ant Colony Optimization (ACO) Algorithm*

The ACO is developed according to the observation that real ants are capable of finding the shortest path from a food source to the nest without using visual cues. To illustrate how the "real" ant colony searches for the shortest path. The goal of the ants is to bring the food back to their nest. Obviously, the shorter paths have advantage compared with the longer ones. This is broadly applied in different system and application in calculation of short path or route in addressing the Traveler Salesmen Problem and Vehicle Routing Problems.

The general formula of Ant Colony Optimization (ACO) Algorithm is expressed as follows:

$$p_{ij}^{k} = \begin{cases} \frac{[\tau_{ij}]^{\alpha} \cdot [\eta_{ij}]^{\beta}}{\sum_{s \in allowed_k} [\tau_{is}]^{\alpha} \cdot [\eta_{is}]^{\beta}} & j \in allowed_k \\ 0 & \text{otherwise} \end{cases}$$

where τij is the intensity of pheromone trail between cities i and j, α the parameter to regulate the influence of τij, ηij the visibility of city j from city i, which is always set as 1/dij (dij is the distance between city i and j), β the parameter to regulate the influence of ηij and allowed k the set of cities that have not been visited yet, respectively.

At the beginning, l ants are placed to the n cities randomly. Then each ant decides the next city to be visited according to the probability. After n iterations of this process, every ant completes a tour. The ants with shorter tours should leave more pheromone than those with longer tours. Therefore, the trail levels are updated as on a tour each ant leaves pheromone quantity given by Q/Lk, where Q is a constant and Lk the length of its tour, respectively. On the other hand, the pheromone will evaporate as the time goes by. Then the updating rule of τij could be written as follows:

$$\tau_{ij}(t+1) = \rho \cdot \tau_{ij}(t) + \Delta\tau_{ij}$$

$$\Delta\tau_{ij} = \sum_{k=1}^{l} \Delta\tau_{ij}^{k}$$

$$\Delta\tau_{ij}^{k} = \begin{cases} Q/L_k & \text{if ant } k \text{ travels on edge } (i,j) \\ 0 & \text{otherwise} \end{cases}$$

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where t is the iteration counter, ρ ϵ [0, 1] the parameter to regulate the reduction of τ_{ij}, $\Delta\tau_{ij}$ the total increase of trail level on edge (i, j) and $\Delta\tau_{ijk}$ the increase of trail level on edge (i, j) caused by ant k, respectively.

- *Participants of the Study*

Thirty (30) evaluators participated in the evaluation of the mobile application. They were travelers or regular commuters. The thirty travelers used the application with its distinct features. This sample was chosen or selected by their usual activities which are frequent travelers within Tibiao, Antique, Philippines.

- *Data Gathering Instruments and Techniques*

In the collection of the needed data, a standardized survey instrument based on the ISO 25010 Software Quality Characteristics was used to gather the needed data, this instrument was designed and abided by most international universities and companies in computer sciences. The standard instrument was divided into four parts which addresses, respectively, the following subjects: quality model; external metrics; internal metrics; and quality in use metrics. ISO 25010 represents the latest (and ongoing) research into characterizing software for the purposes of software quality control, software quality assurance and software process improvement (SPI).

- *Preparation of Instruments*

Irrespective of the field of study for defining data, accurate data collection is essential in maintaining the integrity of the research. Both the selection of appropriate data collection instruments and clearly outlined instructions for their correct use reduce the likelihood of errors to occur. The researcher adopted the instrument of the ISO 25010 standards that were distributed to the participants to be able to come up with data in actual testing of the system for the proposed study.

- *Validation of Instrument*

The reliability of the instrument is the extent to which an instrument of measure yields the same result when used repeatedly. The initial instrument (Survey Questionnaire) was adopted by the researcher from ISO 25010, though the instrument is already standard and recognized by the most institution acknowledging that it is applicable to any software product assessment, this however will still be presented to the be validated by the panelists and the adviser of the study.

- *Data Gathering Procedure*

In gathering the data, the researcher conducted an orientation to the participants who were set to be travelers for the flow of system testing in the actual travel on road then distribute personally the survey questionnaire to them before the testing or the simulation proper begins. The participants were only allowed to answer the evaluation form at the time set, this allowed synchronized start point for the testing phase. Continuation of evaluation of the ISO 25010 characteristics was done to better observe the performance of developed system.

- *Statistical Tools*

When the questionnaires were retrieved, the data were presented in accordance to the sequence of the objectives of the study in tabular forms for ease of comprehension. In order to organize, analyze, and summarize the data needed and to finalize the results.

- *Weighted Mean*

The weighted mean for each item will be obtained by multiplying the scale value of responses by the total number of responses indicating it to get the total weighted points and then dividing them by the total number or responses. The mean is the measure of central tendency. It points to where the majority of the participants' answers to a question cluster.

Where:
X= Weighted Mean
f=Frequency
X =Scores
n = Total number of participants
∑ = Summation symbol

- *Likert Scale*

In the interpretation of the Weighted Mean (WM), Likert's Scale method was employed by the researcher using the following intervals and verbal interpretations. This 5-point scale was used in order to determine the rank of or the adjectival description of the weighted mean of the responses on the observed characteristic of the system. The fields represent the rating, range, and the adjectival description for each rating. These ratings are:

Unit Weight	Equivalent Weighted Points	Verbal Interpretation
5	4.51 – 5.00	Strongly Agree (SA)
4	3.51– 4.00	Agree (A)
3	2.51 – 3.50	Neutral (N)
2	1.51 – 2.50	Disagree (D)
1	1.00 – 1.50	Strongly Disagree (SD)

Table 1:- Likert Scale with Verbal Interpretation

Characteristic	Rating					Mean	Interpretation
Functional Suitability	5	4	3	2	1		
➢ Completeness	21	8	1			4.70	SA
➢ Correctness	16	14				4.57	SA
➢ Appropriateness	18	12				4.60	SA

Table 2:- Functional Suitability of the Application

Table 2 shows that the respondents are in agreement with the functional stability as to completeness, correctness, and appropriateness of the system as proven by the results of the evaluation. Furthermore, the results of the mean, 4.70, 4.57, and 4.60 are interpreted as "Strongly Agree", which means that the system suits to what are being required by the respondents.

Characteristic	Rating					Mean	Interpretation
Performance Efficiency	5	4	3	2	1		
➢ Time Behavior	20	10				4.67	SA
➢ Resource Utilization	19	11				4.63	SA
➢ Capacity	19	11				4.63	SA

Table 3:- Performance Efficiency of the Application

Table 3 shows that the respondents are in agreement with the performance efficiency as to time behavior, resource utilization, and capacity of the system as proven by the results of the evaluation. Furthermore, the results of the mean, 4.67, 4.63, and 4.63 are interpreted as "Strongly Agree", which means that the system performs efficiently.

Characteristic	Rating					Mean	Interpretation
Compatibility	5	4	3	2	1		
➢ Co-existence	20	10				4.67	SA
➢ Interoperability	17	10	3			4.59	SA

Table 4:- Compatibility of the Application

The table above shows that the respondents are in agreement with compatibility of the system as to co-existence and interoperability of the system as proven by the results of the evaluation. Furthermore, the results of the mean, 4.67, and 4.59 are interpreted as "Strongly Agree", which means that the system is compatible to where it would be installed.

Characteristic	Rating					Mean	Interpretation
Usability	5	4	3	2	1		
➢ Appropriateness and Recognition Ability	23	7				4.77	SA
➢ Learnability	20	10				4.72	SA
➢ Operability	18	12				4.60	SA
	14	13	3			4.48	SA
➢ User Error Protection	18	12				4.60	SA
	20	10				4.67	SA
➢ User Interface Aesthetics							
➢ Accessibility							

Table 5:- Usability of the Application

The table above shows that the usability aspect of the system which is being elaborated further by its characteristics, shows that it is being agreed by the respondents. The computed mean, 4.77, 4.72, 4.60, 4.48, 4.60, 4.67, where all have an interpretation of Strongly Agree, would say that the system is really usable.

Characteristic	Rating					Mean	Interpretation
Reliability	5	4	3	2	1		
➢ Completeness	18	12				4.60	SA
➢ Correctness	16	14				4.53	SA
➢ Appropriateness	18	12				4.60	SA

Table 6:- Reliability of the Application

Table 6 shows that the respondents are in agreement with the reliability as to completeness, correctness, and appropriateness of the system as proven by the results of the evaluation. Furthermore, the results of the mean, 4.60, 4.53, and 4.60 are interpreted as "Strongly Agree", which means that the system is something that you can rely on.

Characteristic	**Rating**					**Mean**	**Interpretation**
Security	5	4	3	2	1		
➢ Confidentiality	18	12				4.60	SA
➢ Integrity	17	12	1			4.53	SA
➢ Non-repudiation	15	14	1			4.47	SA
	17	10	3			4.47	SA
➢ Accountability	18	12				4.60	SA
➢ Authenticity							

Table 7:- Security of the Application

The table above shows the results of the evaluation of the security of the system where majority of the evaluators favored the system. Almost all of the computed mean, 4.60,4.53, 4.47, 4.47, and 4.60 of all the characteristics with regards to security, are interpreted as Strongly Agree.

Characteristic	**Rating**					**Mean**	**Interpretation**
Maintainability	5	4	3	2	1		
➢ Modularity	18	12				4.60	SA
➢ Reusability	19	9	2			4.61	SA
➢ Analyzability	15	13	2			4.43	A
	18	11	1			4.57	SA
➢ Modifiability	18	12				4.60	SA
➢ Testability							

Table 8:- Maintainability of the System

The table above shows that the respondents agreed with the maintainability as to modularity, reusability, analyzability, modifiability, and testability of the system as proven by the results of the evaluation. Furthermore, mostly all the results of the mean, 4.60, 4.61, 4.43, 4.57, and 4.60 are interpreted as "Strongly Agree", which means that the system is maintainable.

Characteristic	**Rating**					**Mean**	**Interpretation**
Portability	5	4	3	2	1		
➢ Adaptability	18	12				4.60	SA
➢ Installability	18	12				4.60	SA
➢ Replaceability	20	7	3			4.57	SA

Table 9:- Portability of the System

The data in Table 9 show that the respondents are in congruence with portability as to adaptability, installability, and replaceability of the system as proven by the results of the evaluation. Furthermore, the results of the mean, 4.60 4.60, and 4.57 are interpreted as "Strongly Agree", which means that the system has met the portability characteristics.

Characteristic	**Rating**					**Mean**	**Interpretation**
	5	4	3	2	1		
➢ Effectiveness	18	12				4.60	SA

Table 10:- Effectiveness of the System

The results as reflected in the above table show that the evaluators found out that the system is effective. Furthermore, the computed mean, 4.60 would attest that the system could really function as it was designed.

Characteristic	Rating					Mean	Interpretation
	5	4	3	2	1		
➢ Efficiency	18	12				4.60	SA

Table 11:- Efficiency of the System

The results as reflected in Table 11 show that the evaluators found out that the system is efficient. Furthermore, the computed mean, 4.60 would prove that the system could really function very well and could give results ahead of expected time.

Characteristic	Rating					Mean	Interpretation
Satisfaction	5	4	3	2	1		
➢ Usefulness	17	13				4.57	SA
➢ Trust	18	12				4.60	SA
➢ Pleasure	21	9				4.70	SA
	22	8				4.73	SA
➢ Comfort							

Table 12:- Satisfaction of the Application

Table 12 shows that the respondents are in agreement with the so-called satisfaction as to usefulness, trust, pleasure, and comfort of the system as proven by the results of the evaluation. Furthermore, the results of the mean, 4.57, 4.60, 4.70, and 4.73 are interpreted as "Strongly Agree", which means that the evaluators were satisfied with the functions of the system.

Characteristic	Rating					Mean	Interpretation
Freedom from Risk	5	4	3	2	1		
➢ Economic Risk Mitigation	16	10	4			4.40	SA
➢ Health and Safety Risk Mitigation	23	7				4.77	SA
➢ Environmental Risk Mitigation	21	9				4.70	SA

Table 13:- Freedom from Risk of the System

The table above shows that the respondents were not afraid of the risks the system would encounter incase. The computed mean would attest that the system would be able to overcome whatever dangers that may occur.

Characteristic	Rating					Mean	Interpretation
Context Coverage	5	4	3	2	1		
➢ Context Completeness	23	7				4.77	SA
➢ Flexibility	19	11				4.63	SA

Table 14:- Context Coverage of the System

The table above shows that as to context coverage which includes context completeness and flexibility, majority of the respondents are in congruence with the system. The results of the computation of the mean, 4.77 and 4.63 signified that context of the system is being appreciated by the said respondents.

Traveler	Start Point	Destination	Time Estimation without Application	Travel Tine with Application
1	Point A	Endpoint	60 minutes	35 minutes
2	Point B	Endpoint	45 minutes	25 minutes
3	Point C	Endpoint	30 minutes	20 minutes
4	Point D	Endpoint	40 minutes	25 minutes
5	Point E	Endpoint	50 minutes	30 minutes

Table 15:- Comparison of Travel Time with the Use and Without Use of the Application

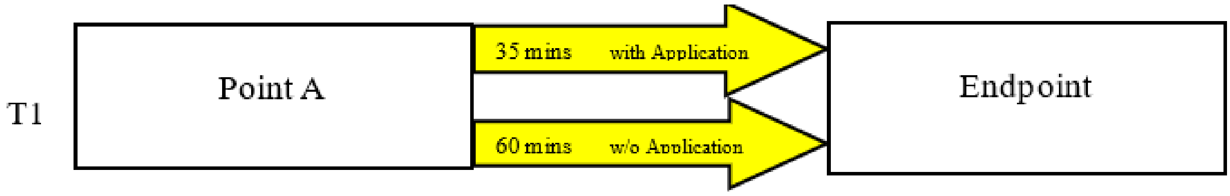

Fig 2:- Test of Quality Best Route of Respondent 1

The figure above shows the quality best travel time from Point A to the Endpoint. It is reflected that with the use of the application it took 35 minutes travel time while without the use of application, it took 60 minutes to reach the destination. Since the computed travel time to arrive has a quality best route of 0.58, which is below , 0.70, therefore, the application has the quality best travel route.

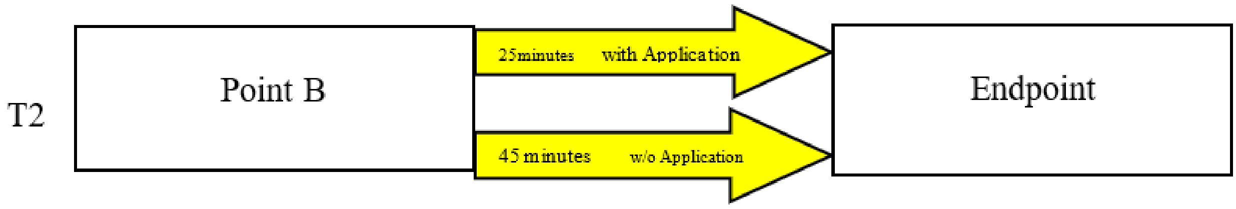

Fig 3:- Test of Quality Best Route of Traveler 2

Figure 2 shows quality best travel time from Point B to the Endpoint. It shows that with the use of the Application it took 25 minutes travel time while without the use of application it took 45 minutes to reach the destination. Since the computed travel time to arrive has the quality best route of 0.56, which is below 0.70, it is considered that the application has the quality best travel route.

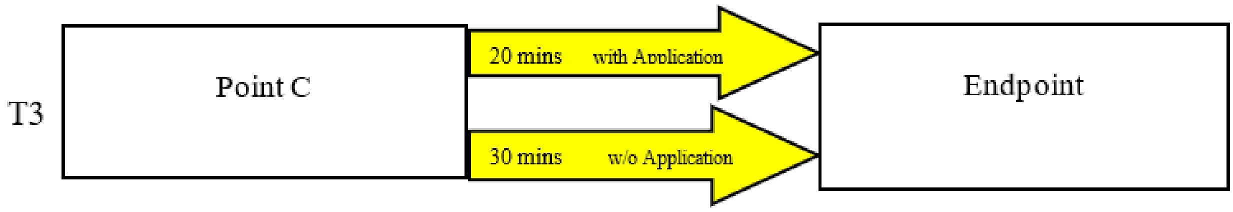

Fig 4:- Test of Quality Best Route of Traveler 3

The data in the figure above show quality best travel time from Point C to the Endpoint. It is reflected that with the use of the application it took 20 minutes travel time while without the use of application it took 30 minutes to reach the destination. Since the computed travel time to arrive has a quality best route of 0.67, which is below to 0.70, the application has the quality best travel route.

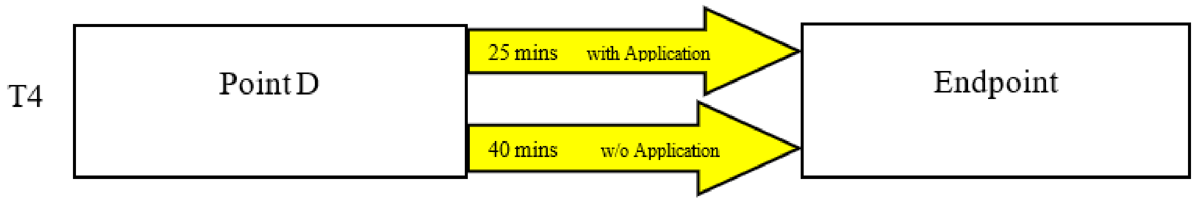

Fig 5:- Test of Quality Best Route of Traveler 4

The figure above shows quality best travel time from Point D to the Endpoint. It is evident that with the use of the application it took 25 minutes travel time while without the use of application it took 40 minutes to reach the destination. Since the computed travel time to arrive has the quality best route of 0.63, which is below to 0.70, the application has the quality best travel route.

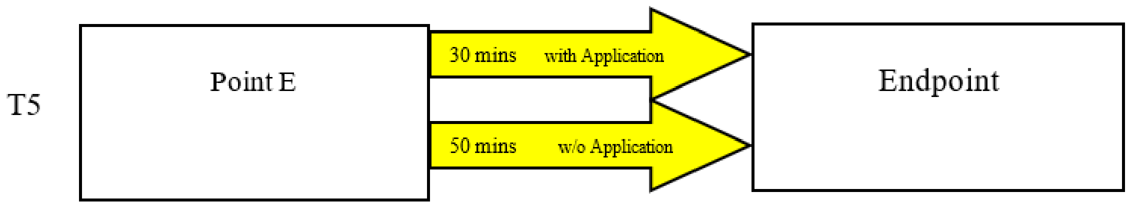

Fig 6:- Test of Quality Best Route of Traveler 5

Figure 6 shows the quality best travel time from Point E to the Endpoint. It shows that with the use of the application it took 30 minutes while without the use of application, it took 50 minutes to reach the endpoint. Since the computed travel time to arrive has the quality best route of 0.60, which is below to 0.70, the use of the application has the quality best travel route.

$$q_{best} = \frac{min_{k \in R}(tts_k)}{tts_{stat}}$$

Where $min_{k \in R}$ = is the set of all routes found by the ants;

(tts_k) = is the total time spend by the vehicle if it was to use route k

tts_{stat} = is the total time spend by the vehicle if it was not to choose the result obtained using Application.

qbest-value can be as low as 0.7. Meaning a 30% reduction of time spend for the vehicles.

$$q_{best} = \frac{min_{k \in R}(tts_k)}{tts_{stat}}$$

= 1(20)/60

= 0.49

Fig 7:- Sample Computation of the Test Quality Best Route of Ant Colony Optimization

The above figure shows the process of computing the Test Quality Best Route of Ant Colony Optimization. The computed result of the test quality best route is 0.49, which means that the use of the application is efficient for the computed value is less than .70.

III. CONCLUSIONS

After the thorough analysis and evaluation of the data gathered from the participants through the initial testing and their evaluation, the researcher came up with the following conclusions:

- The use of Test Quality Best Route of Ant Colony Optimization has improved "the user's travel comfort".
- The Test Quality Best Route of Ant Colony Optimization algorithm has better optimization ability and user comfort than the baseline algorithms.
- ACO's pheromones show that the shortest the path, the stronger is the concentration as proven through the simulation of the application.

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