Saving Matrix Method for Efficient Distribution Route Based on Google Maps API

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Abstract—**This research presents a method for solving distribution route problem for the company to be able to deliver goods or products to customers effectively. Using a website to determine distribution routes, the company can save the shipping cost in the delivery of goods to company branch or to customers directly. Therefore, it is necessary to schedule and pinpoint the delivery route appropriately so the route that has been taken can be more efficient in terms of distance, time, and cost. Saving Matrix is a method to minimize distance, time, and cost to produce an efficient delivery route. In Saving Matrix method requires the distance between the warehouse owned by a company and the destination of goods delivery, originating from the warehouse company. Google Maps API (Application Programming Interface) as service from Google that provides maps containing location information from around the world it is used to determine the distance. Users can directly fill the location of the warehouse, destination location, and vehicle data through the website. Then the website calculates the distance by using Saving Matrix method and show the optimal distribution routes for the company.**

Index Terms—**Distribution Route; Google Maps API; Saving Matrix Method.**

I. INTRODUCTION

Distribution route is considered as one of the important factors for the company to be able to distribute goods or products to customers. In the distribution of goods or products, the punctuality of delivery is one of the main factors to increase customer satisfaction. In addition, the company must also consider regarding the shipping cost in the delivery of goods to the branch company or customers directly. Therefore, it is necessary to schedule and pinpoint the delivery route appropriately so that the route taken can be more efficient in terms of distance, time, and cost. One of a method for determining the delivery route is Saving Matrix method.

Saving Matrix is a method to minimize distance, time, and cost to produce an efficient delivery route. With Saving Matrix method, is expected to help companies in their distribution network. In Saving Matrix method requires the distance between the warehouse owned by a company and the destination of goods delivery, originating from the warehouse company.

For determining the distance, supported by the development of information technology today, there are many online application services that can search a location. One of the online application that can search location is Google Maps. Google Maps is a service from Google that provides maps containing location information from around the world. With the development of information technology today, Google also provides API (Application Programming

Interface) for the developer to use and develop applications owned by Google including Google Maps. Google Maps can be integrated into the web or application that is being created.

II. RESEARCH METHODOLOGY

A. Distribution

Physical distribution channels are terms used to describe methods and means by which a product or group of products is physically transferred, or distributed, from a production point of view to the point where the product is available to the final consumer [1]. Distribution is a key to the company's profits because direct distribution will affect the cost of the supply chain and consumer needs. An appropriate distribution network can be used to achieve the various objectives of the supply chain, from low cost to high response to the demand of consumers.

B. Saving Matrix Method

Generally, the problem of scheduling and determining delivery routes can have several goals to be achieved such as the goal to minimize shipping costs, minimize the time, or minimize mileage. In the language of a mathematical program, one of these objectives can be a function objective (objective function) and the other becomes a constraint (constraint). For example, the objective function is to minimize shipping costs, but there are time window constraints and maximum mileage constraints per vehicle, in addition to other constraints such as vehicle capacity or other constraints.

C. Google Maps API

API is an acronym for Application Programming Interface. In simple languages, the API is the programming functions provided by the application or service so that the service can be integrated with the created application. Google Maps API is the programming functions provided by Google Maps so that Google Maps can be integrated into the web or application that is being created.

D. Unified Modeling Language (UML)

UML which is an acronym for Unified Modeling Language is a set of modeling conventions used to define or describe a software system in relation to objects [2]. UML can also be defined as a standard graphical language used to model object-based software. Modeling is actually used for simplifying complex issues in such a way that it is easier to learn and understand. The purpose of Unified Modeling Language is to provide a general object-based vocabulary, rich enough to modeling every system development project from analysis to design.

E. *Prototyping Model*

The prototype Model is one of the most widely used software development methods. Prototyping can occur at a number of points in the design process. With this Prototyping Method, developers and customers can interact with each other during the process of making the system [3]. It often happens that a customer only defines in general what is required, what processing and data are needed. On the other hand, the developers are less concerned about the efficiency of the algorithm and the ability of the operating system and the interfaces that connect people to computers.

III. RESULT AND DISCUSSION

Before creating a website, performing system analysis is very important, so the website to be built has the basic and general description.

A. *Website Users and Their Needs*

The scope of this research, the website will provide delivery route determination services for the company. The user permissions on the website will be divided into 3 types of permissions:

1. Guest: Users who visit the website. Facilities owned by the guest are as follows:
   - Find the location on the website.
   - Manage shipping data i.e.: warehouse data, destination data, and vehicle data.
   - Searching for the optimal route on the website.
   - Register on the website.
2. Member: Users that already registered on the website. Emails that have been used to register as a sub-member cannot be used again to register as a member. Member has all the facilities that a guest can do and with the following additional facilities:
   - Login to the website.
   - Manage route data which include saving, modifying, and deleting.
   - Manage sub-member.
3. Sub-member: Users that registered members on the website. Sub-member can only see routes that have been created by members. Sub-members are users who travel a route that already created by a member. An example of a sub-member is a driver or a driver assistant. Emails that have been registered as a member cannot be used to register as a sub member. Facilities owned by sub-members are as follows:
   - Login to the website.
   - See route that already created by a member.

B. *System Analysis*

In this sub-chapter system analysis is done on the website that will be created and the activities undertaken by the company on the system. Analysis performed include the stages of the system ranging from loading data including vehicle data, warehouse and delivery purposes and process calculation method Saving Matrix. The whole process along with the Saving Matrix method calculation steps performed by the website is illustrated in the following flowchart.
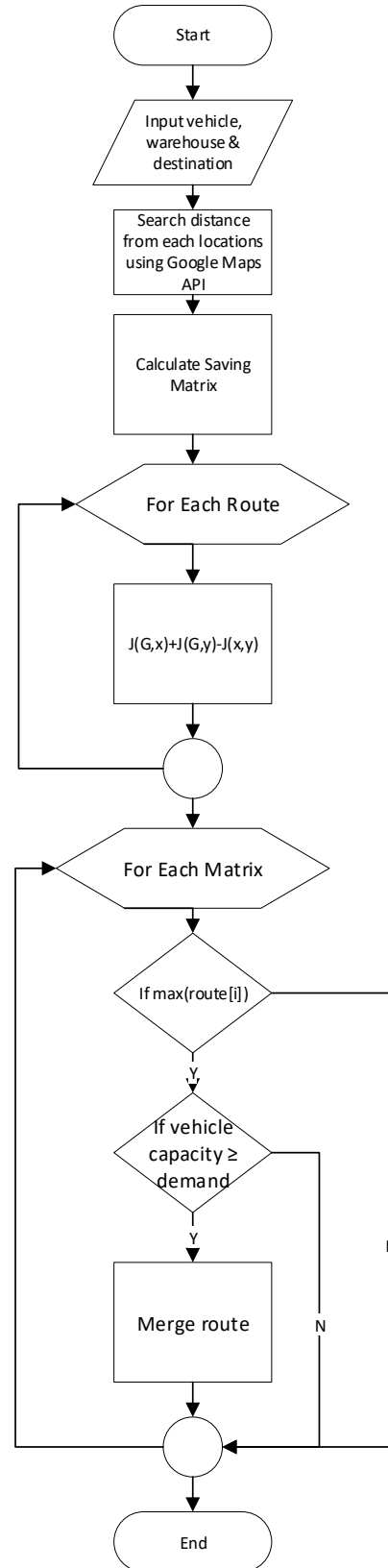

Figure 1: Flowchart Saving Matrix Calculation Process

Referring to Figure 1, the first thing to do is the company must fill in the location of the warehouse and the location of the delivery destination on the website. In determining the location of the warehouse and delivery destination, the website made use of Google Map API so that the website directly connected to Google servers to get features owned by Google Maps.

Furthermore, the company will fill in the number of

shipping requests from each destination location. The company then also has to fill in the number of vehicles used to make the delivery as well as the capacity that can be transported by the vehicle in a single shipment. After that, the website will do the calculation to find the optimal route by using Saving Matrix method. Saving Matrix calculation process itself includes the process of calculating the distance from the warehouse location to each delivery destination and the distance between each destination that has been determined by the company. In this research, the process of calculating the distance will also be done using the Google Maps API so that the website can instantly get the distance.

After obtaining the distances for each location, then it will be calculated using saving matrix by combining the delivery route as below:

$$S(x, y) = J(G, x) + J(G, y) - J(x, y) \qquad (1)$$

where:

$S(x,y)$ = Saving Matrix value or the combined distance
$J(G,x)$ = distance from warehouse to destination x
$J(G,y)$ = distance from warehouse to destination y
$J(x,y)$ = distance from destination x to destination y

After each value obtained from the savings of the route, it can be done the allocation of delivery destination to the vehicle or route. Then after the route obtained from the calculation results, it will be determined the order of delivery by the method of Farthest Insert, Nearest Insert, and Nearest Neighbor. The results obtained from the three methods were compared and selected which resulted in a minimum distance, as illustrated in the following flowchart on Figure 2.
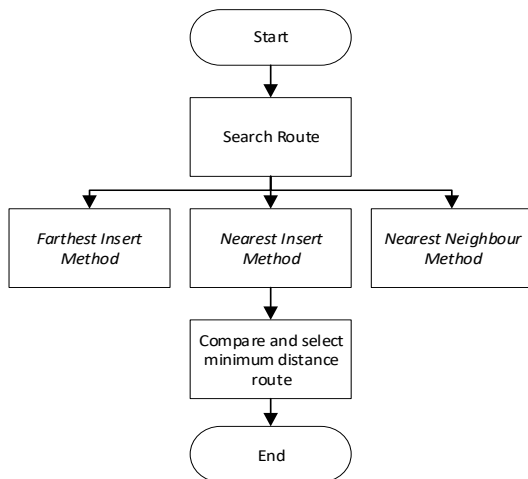

Figure 2: Flowchart Sorting & Selected Route

Finally, the website will display the route generated from the calculation using the Google Maps API.

In a distribution process that usually included in a supply chain, a company will perform a distribution plan known as the Distribution Requirement Planning (DRP) [4]. Then from the calculation of DRP can be known the quantity of distribution that is sent to each delivery destination and then can be searched route to be passed by the vehicle to distribute the product. Here, the role of Saving Matrix is needed as a method to make the distribution savings from the side of delivery route through which the vehicle will get an optimal delivery route.

In this research, the authors retrieve data from previous research using Saving Matrix to save shipping cost. From the previous research, the delivery data will be taken which will be used as data input to conduct trial calculation Saving Matrix through the website. The research data which taken is from Effendi et al. (2016) who research titled "Penentuan Rute Optimal Distribusi Produk Dengan Metode Saving Matrix Dan Traveling Salesman Problem Di PT. Romindo Primavetcom" [3]. This research uses Saving Matrix method with Traveling Salesman Problem (TSP) which is used as route sorting method. Research conducted addressed to PT. Romindo Primavetcom which is a company engaged in marketing and distribution of drugs, vaccines and vitamin feed addictive for animals and having their address at Kendang Sari No. 20, Jemur Wonosari, Wonocolo, Surabaya.

In the making of the distribution route determination website will utilize Google Maps API to facilitate users in search location and will also be used to display routes that have been made by website users. The Google Maps API has several different types of APIs that are differentiated according to the type of application needs that will be created by app developers [5]. The API used for website distribution route determination is the Google Maps Javascript API. The Google Maps Javascript API has many accessible functions for manipulating maps or Google Maps used on a website. The limit of using the free version of Google Maps API functionality is 2,500 access per 24 hours. Here are the functions used for website creation of distribution routes and their usefulness in the website:

1. Map
   To display the map on the website, the Map function is used. The process used on the website to access the Google Maps API is an asynchronous process. With the asynchronous process, the process to access Google Maps API processed separately or not wait to complete one process first.

2. Autocomplete
   To search for a location using a textbox. Autocomplete will display the location according to the letters or words entered in the textbox. On the website created, autocomplete is used to locate the warehouse and delivery destination by using the text box available on the website.

3. Marker
   To mark a place on a map that is usually an icon that appears on the map. Markers are added when the user searches for locations with the autocomplete function or clicks on the map. The color or shape of the marker icon used can be changed as provided by the Google Maps API. Markers are used to mark the warehouse and delivery destination on the website created. The warehouse is marked with a blue marker and red delivery destination. When displaying a route, the marker will also display a shipping sequence in the form of a text sequence of submissions.

4. Info window
   Used to display the information that appears on the marker. Information will appear in the form of a text window above the marker icon and can be closed or reappeared. On the website to be created, the info window displays information from the warehouse and delivery destination in the name of the location, address, and number of requests.

5. Geocoder

Geocoder function is used to get information from a location based on input latitude and longitude. On the website created, geocoder is used to retrieve information from the location when the user clicks on the map. Geocoder will retrieve location information and display it on the website.

6. Distance Matrix Service

To retrieve distance information from two or more locations on the map by inputting latitude and longitude input. On the website to be created, distance matrix service is used to obtain the warehouse distance and delivery destination before the calculation using Saving Matrix method begins. Distance matrix service has a limit on its use as defined by Google. The limit for each access is 100 elements in which the element is the requested distance when accessing the distance matrix service. In addition, distance matrix service has access limit of 100 elements every second. To access more of these limits, separation is done when accessing distance if location exceeds 10 and given pause before re-accessing distance matrix service.

7. Direction Service

To show the route on the map, the direction service is used. The direction service can display routes from two locations by entering the original location and destination. To display routes with multiple destination locations, there is a waypoint feature in the direction service. By using a waypoint, the route can go through many locations at once with just one access. In the created website, the direction service is used to display the processed delivery route using the Saving Matrix method. Just like the distance matrix service, direction service also has a limit when accessing 23 locations each access and 50 access every second.

C. Use Case Diagram

Use Case Diagram describes the sequence of activities performed by actors or actors and systems to achieve a particular goal, describes the expected functionality of a system, and presents the interaction between actors or actors with the system [6]. In the use case diagram will be seen the actors who use the system and activities that can be done by the actor.

Use case diagrams on the website describe how a system involves one or more actors in their activities. On the website to be designed, there are three types of actors are the guest, member, and sub-member. For each type of actor has a use case in accordance with their needs. Figure 3 shows the use case diagram for each type of website user determining the distribution route to be created.

In Figure 3, each user can be found on the system. Guest is a user who has not registered yet. Guest has limited facilities on the system that is managing data delivery, finding location, processing the optimal route search, and registration. Member is a user who has registered on the website. Member can manage sub data member and manage route data which were when managing route data, the member also can manage delivery data. Then sub-member is a user registered by the member and can only log in and see route which has been made by the member.
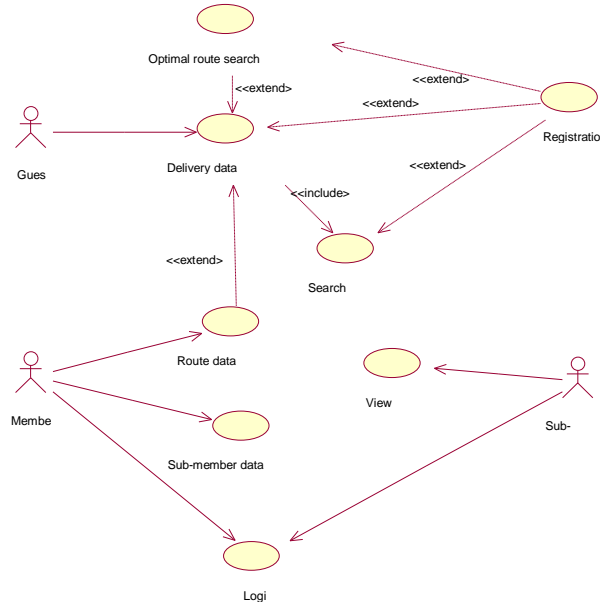

Figure 3: Use Case Diagram for Distribution Route System

D. User Interface

In this sub-chapter display the user interface from the distribution routes determination website that has been made. The distribution route determination website is built using a combination of PHP, HTML, and JavaScript, and some MySQL statements laid out using CSS, and possibly utilizing various HTML5 elements [7].

- Home Page View

Refer to figure 4 shows the main page of the website which has several menus to access the main content inside it, such as login page for registered user and display-route page.

Figure 4: Home Page

- Create Route Page

Referring to Figure 5, the create-route page is used to fill delivery data, where in the end user can search the best route through website.
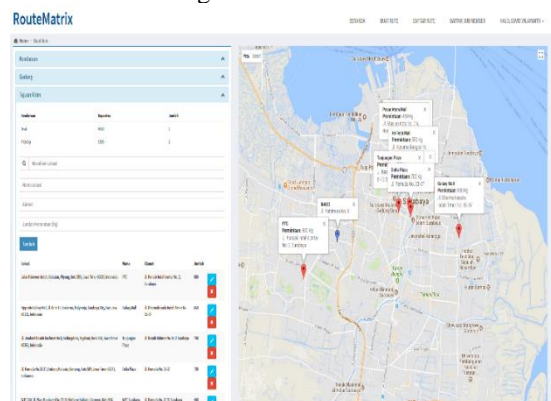

Figure 5: Create-Route Page

- Displaying Routes View
  Figure 6 shows how the website displays the shortest route based on user input. Once the website displays the route, users can store, change or print the delivery routes for future use.
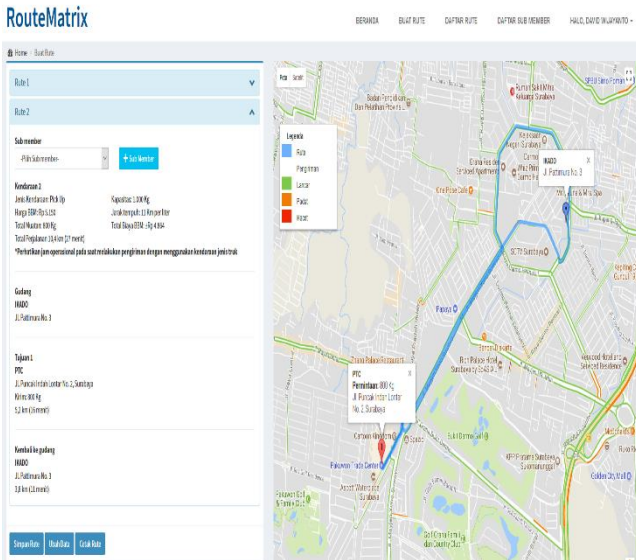

Figure 6: Display Route Page

- Registration Page View
  The registration page (Figure 7) can be accessed by users who want to get full access within the website. In this case, the company will register as a member of the website. The benefits that can be obtained as a member of this website is that members may save, change or print delivery routes for future purposes.
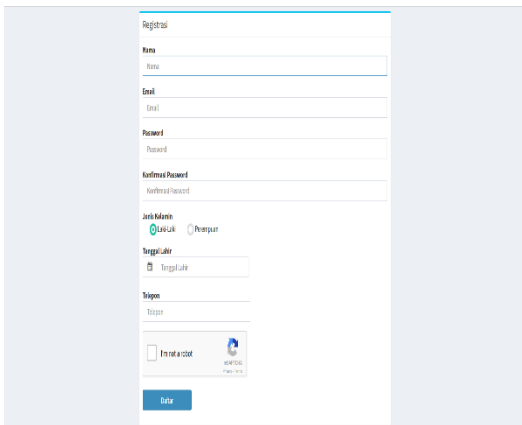
Figure 7: Registration Page

- Login Page View
  Referring to Figure 8, the login page used by users who have registered as a member of the website. They must log in to get full access within the website.
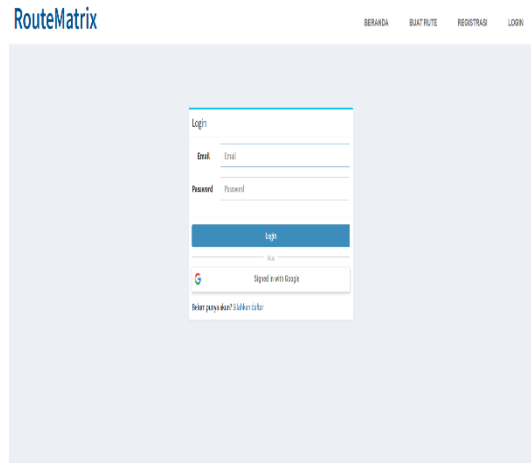

Figure 8: Login Page

- Routes List Page View
  The list page (Figure 9) is used to allow members to view routes that have been made on the website. Member can view delivery data such as list and number of routes, and number of destination locations that have been made before.

Figure 9: List Page

- Sub-members List Page View
  The sub-member list page (Figure 10) is used by members to view the list of sub-members that have been registered on the website. Member can see the name, email, and route number owned by sub member.

Figure 10: Sub-Member List Page

E. *Testing*

Testing that will be conducted on the website will take advantage of black box testing methods on which the user without knowledge of the internal structures of a website, tests the web pages by using a browser, providing inputs (clicks, keystrokes) and verifying the outputs against the expected outcome. It will also be tested Saving Matrix method on route generated by website with calculation result made separately:

a. In the testing scenario using Effendi et al. data [8], the route generated by the website is not the same. Because at the time of trial, the location point entered into the website has a difference in the distance so when calculating the distance between each location, the result is different. Testing results on the website with scenarios from Effendi et al. data [8] are shown in Table 1.

b. Website is able to determine and display routes that can assist users in distributing goods.

c. If the user enters a requested capacity greater than the available load capacity of the vehicle, the website will display a route by dividing the request to another vehicle or making alternating shipments using a single vehicle.

Table 1
Testing Result

Methods	Routes	Distance (Km)
Route 1		
Farthest Insert	C0-C6-C15-C13-C3-C17-C11-C0	665,0
Route 2		
Nearest Neighbour	C0-C7-C5-C14-C9-C10-C8-C1-C2-C0	190,8
Route 3		
Nearest Insert	C0-C4-C12-C16-C0	47,1

IV. CONCLUSION

The conclusions that can be taken from the process of making the distribution route determination website based on Saving Matrix Method is the website can determine the distance traveled from a predetermined location by utilizing the Google Maps API. In addition, there are also three other methods used to sort the result of delivery route, which is Farthest Insert, Nearest Insert, and Nearest Neighbors. Furthermore, the free services from Google Maps API can only access 10 locations of origin and 10 destination locations simultaneously. Therefore, the authors divide the location by utilizing the array and doing the process looping until all the distance of the location is obtained.

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