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GEOGRAPHICAL INFORMATION SYSTEM SHORTES PATH DELIVERY OF GOODS USING THE BELLMAN-FORD AND DIJKSTRA ALGORITHM (CASE STUDY J&T PALU CITY)

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ABSTRACT
The demand for goods delivery services (expedition services) is currently growing very rapidly to support the many e-commerce companies that have sprung up in Indonesia. In the delivery process, there is often a delay in delivery due to the random delivery path of the delivery service courier. The development of information technology, especially computer technology, can be used to solve problems in various fields of work. This study aims to optimize the determination of Goods Delivery routes using the Bellman-Ford and Dijkstra Algorithms. The case study was conducted at J&T Goods Delivery Services in Palu City, Central Sulawesi. The data used in this study is the distance data between the delivery location points of goods taken from Google Maps. This research was conducted by collecting data on the distance between the source point and the location of the delivery of goods. By using the Bellman-Ford and Dijkstra Algorithms, the Bellman-Ford Algorithm is used to handle graphs with negative weights and detect negative cycles, while the Dijkstra Algorithm is more efficient on graphs with positive weights, focusing on finding the shortest path from one point to all other points, the distance and time required for shipping goods can be minimized so that the efficiency of shipping goods can be increased.

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I. INTRODUCTION

In the current era of globalization, the need for shipping services has increased quite rapidly. Delivery services are part of consumer needs. Consumers who use this goods delivery service tend to want something that is fast, easy, safe and practical in terms of shipping goods[1]. Freight forwarding is one of the most widely used services today. This is because goods delivery services play an important role in all fields and needs, One of them is in the online buying and selling process[2]. The demand for goods delivery services (expedition services) is currently growing very rapidly to support the many e-commerce companies that have sprung up in Indonesia. In the delivery process, there is often a delay in delivery due to the random delivery path of the delivery service courier[3].

In traveling, the shortest route is always a priority so that travel is more efficient both in terms of time and cost, so that in the delivery of goods there are often delays when delivering goods to consumers, Then it is necessary to determine the shortest distance or path which is a problem to find a path between two nodes with the minimum number of weights, so it is necessary to determine the fastest path between points or locations to be traveled[4][5]. To overcome the above problems, an analysis is needed to determine the paths that will be traveled by couriers in terms of delivery or delivery of goods. In supporting the determination of the path, the Bellman ford algorithm was chosen where the process by calculating the shortest distance from a source starting from one point to another by using a table containing the distance value between two points[6].

The problem of finding the path between two vertices in a weighted graph that has the minimum number of weights on the graph edges traversed is known as the shortest path problem[7]. Shortest path is a problem to find a route on a graph with the shortest distance to get to the final destination by minimizing the sum of the weights of the edges forming the route, If there are two points S and T can be passed through several paths, where the path with the minimum weight is called the shortest path or route. The process of minimizing the weight on a graph path

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is called shortest path There are several types of shortest path problems, namely, determining the shortest path between two predetermined points, the shortest path between all points, the shortest path from one point to all points, the shortest path between two points through several predetermined points[8].

Determining the shortest path requires steps or methods to be able to determine the right and faster path to reach the location point. The algorithms used to determine the shortest path are Dijkstra's algorithm and bellmanf-ford algorithm. The workings of Dijkstra's Algorithm and Bellman-Ford Algorithm use a greedy strategy, where at each step the side with the smallest weight is selected that connects a node that has been selected with another node that has not been selected. Dijkstra's Algorithm and Bellman-Ford's Algorithm require origin, and destination parameters. The end result of this algorithm is the shortest distance from the origin to the destination along with the route[9].

From the research that has been done by researchers written by Serdano Akbar et al, in a journal or scientific work on finding the shortest gas station and determining the shortest distance using the dijkstra algorithm, in this study only determines the shortest distance as a recommendation to be traveled. Therefore, new research was developed using the dijkstra algorithm and the bellman-ford algorithm to find gas stations with the shortest distance and provide a comparison of the two algorithms which is better. The two algorithms certainly have different methods of solving problems so that comparisons need to be made[10]

The selection of the Bellman-Ford and Dijkstra algorithms provides a good balance between efficiency, flexibility, and the ability to handle special conditions in delivery route optimization. This makes them highly relevant and effective in the context of this research. The advantages of other algorithms are as follows.

1. A* (A Star):* While the A* algorithm is very efficient for pathfinding with good heuristics, its application requires deep knowledge of the right heuristics for each case, which may not always be available or easy to determine in complex delivery contexts.
2. Floyd-Warshall: This algorithm is capable of finding the shortest path between all pairs of nodes, but has O(V^3) time complexity, which makes it less efficient for large graphs compared to Dijkstra and Bellman-Ford which are more focused on the shortest path from a single source.
3. Johnson's Algorithm: Although it combines the advantages of Bellman-Ford and Dijkstra and is effective for large graphs, its implementation complexity is higher and not always necessary for everyday delivery cases.

The development of e-commerce has a positive influence which is shown through three indicators, namely the growing quantity of e-commerce websites and applications, increasing users and increasing transaction value. There are aspects that underlie this statement. The first is the historical aspect, namely the existence of a global economy that embraces globalization. Indonesia is also not immune from this. Globalization encourages the transfer of products, technology and others. For example, Indonesia has not been able to produce fighter aircraft independently, but Indonesia can import from countries that are able to produce fighter aircraft. In addition, globalization also accelerates the flow of information to various parts of the world, resulting in the loss of boundaries between one region and another. The growing internet technology is then commercialized and will be the forerunner of the emergence of buying and selling via online. Previously, online buying and selling activities had been carried out in previously developed countries, such as European countries and the United States since 1991. The various conveniences and advances in developed countries offered by online transactions have finally become a trend in the world and Indonesia. This can show that e-commerce is influential in improving the economy in Indonesia[11].

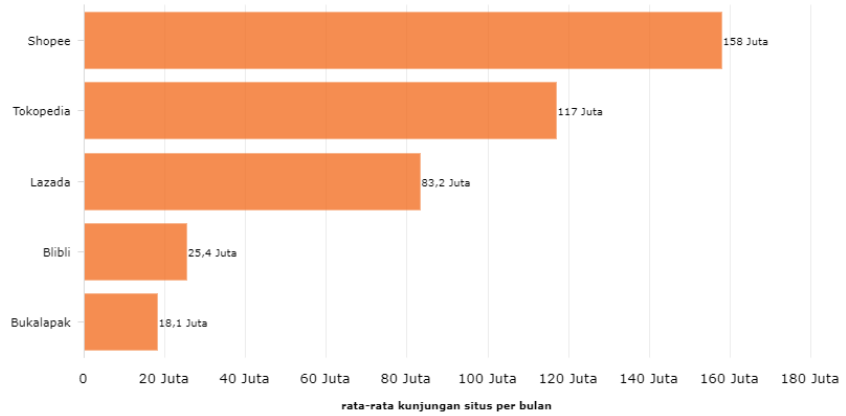

Figure 1 Five E-Commerce With The Most Visitors In Indonesia

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Online expedition services in Indonesia offer a variety of services to attract customers for e-commerce shopping, including the younger generation or gen Z. According to the latest research from Populix released on August 2, 2023, J&T Express is the top choice for gen Z, with 58% of respondents choosing it as their favorite expedition service for online shopping. The same is true for the millennial group, where 52% of respondents chose J&T Express as their favorite expedition service provider for online shopping in 2023[12].

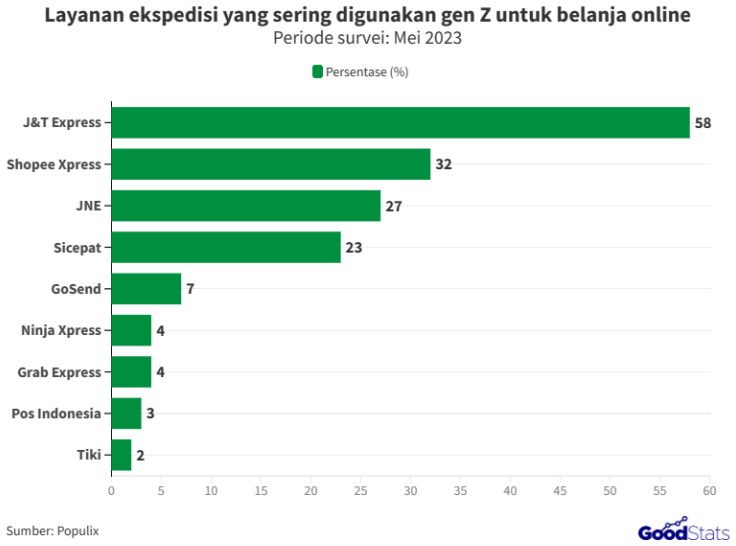

Figure 2 Expedition Services That Are Often Used In Online Shopping

II. RESEACRH METODOLOGY

This research uses a quantitative approach with an experimental method to develop and analyze a Geographic Information System that determines the shortest path for delivering goods using the Bellman-Ford and Dijkstra Algorithms. The search and review of literature related to the Geographic Information System Bellman-Ford and Dijkstra Algorithms, as well as the application of the two algorithms in the context of delivering goods, is studied in a model where a J&T company engaged in shipping services sends its packages through a courier. The authors sampled the area of Tondo village, Mantikulore sub-district, Palu City from Google Maps. Data collection in this study used geographical data and road networks in the study area collected through field surveys and secondary data sources such as digital maps and data from related offices. At this stage, observations and interviews were made to the leaders and officers of J&T Palu City, Central Sulawesi Province to understand the current flow of goods delivery and identify existing problems at the J&T Palu City office. Validation and verification of data obtained from the survey was explained directly by the head of the J&T Palu City office.

Steps in using the Bellman-Ford and Dijkstra algorithms. In Dijkstra's algorithm starting from the start node, select the unvisited node with the shortest distance. Relax all selected nodes. Relaxation means updating to a shorter path through the node being processed. In the bellman ford algorithm, the relaxation on all graph edges |V|-1 times, where |V| is the number of vertices. After that, perform one more iteration to detect any negative cycles.

Choosing Tondo Village, Mantikulore Subdistrict, Palu City as the research area has several strong reasons that can provide better insight in the context of this research. The varied topography and different road conditions allow testing the performance of the Bellman-Ford and Dijkstra algorithms in various terrain situations. In addition, the post-earthquake 2018 infrastructure development, as well as increased economic activity and e-commerce, adds to the relevance of this region for study. The complexity of the delivery route with a variety of road types from main roads to narrow roads in residential areas is suitable for testing the effectiveness of the algorithms. The availability of complete and accurate spatial data also supports the research. This research can provide direct benefits to local communities by optimizing the delivery process, improving logistics accessibility and efficiency, and supporting local economic growth, making it relevant for governments and logistics service providers.

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III. RESULT AND DISCUSSION

A. *Planning*

This algorithm was developed by Richard Bellman and Lester Ford, Jr. This algorithm is very similar to Dijkstra's algorithm but it can handle negative weights in finding the shortest path in a weighted graph. The Bellman-Ford algorithm is a development of Dijkstra's algorithm, the Bellman-Ford algorithm will be correct if and only if the graph does not contain a cycle with a negative weight reached from the source[13], [14]. Dijkstra's algorithm is a greedy algorithm used to solve the shortest distance problem in a directed graph with non-negative edge weights. The underlying idea of Dijkstra's algorithm is to find the shortest cost value to a functioning destination on a weighted graph, which in turn can help determine the choice of path. In Dijkstra's Algorithm, nodes are used because Dijkstra's Algorithm uses a directed graph in determining the closest path[15].

B. *Analisysis*

At this stage, an analysis was carried out through observations and interviews with J&T officers in Palu City, Central Sulawesi Province to understand the current flow of goods delivery and identify existing problems at the J&T Palu City office. This process aims to show that the implementation of this system can improve performance in delivering goods. The implementation of this system is expected to provide an effective solution to the problems that exist in the J&T Palu City office, while increasing efficiency in the delivery of goods.

The implementation of Bellman-Ford and Dijkstra's algorithm in the delivery route optimization system at J&T Tondo has made a significant impact. By mapping the delivery network as a graph and applying the Bellman-Ford and Dijkstra algorithms to find the shortest path, the company managed to significantly reduce delivery time and Reduction of waiting time at the warehouse and driver travel time, saving operational costs such as fuel savings and reduced vehicle maintenance costs, and increasing customer satisfaction with delivery timeliness.

TABLE 1
TABLE OF COMPARISON RESULTS BETWEEN BELLMAN-FORD AND DIJKSTRA ALGORITHMS

Starting Point	Delivery Destination	Distance	Time	Algorithm Computation Time		Conclusion
				Dijkstra	Bellman-Ford	
J&T RE.Martadinata Office	Citraland	2,88 KM	5 Minutes	1,33 Second	0,26 Second	More Bellman-Ford Efficiency
J&T RE.Martadinata Office	Jl. Pendidikan	2,56 KM	5 Minutes	0,29 Second	0,71 Second	More Dijkstra Efficiency
J&T RE.Martadinata Office	Jl. Dayodara	4,42 KM	8 Minutes	1,43 Second	0,38 Second	More Bellman-Ford Efficiency
J&T RE.Martadinata Office	Jl. Untad 1	4,63 KM	11 Minutes	1,38 Second	3,18 Second	More Dijkstra Efficiency
J&T RE.Martadinata Office	Btn Bumi Roviga Tondo	4,27 KM	11 Minutes	0,90 Second	1,15 Second	More Dijkstra Efficiency
J&T RE.Martadinata Office	Perumahan Dosen	3,38 KM	9 Minutes	0,27 Second	0,45 Second	L More Dijkstra Efficiency
J&T RE.Martadinata Office	Taipa	9,86 KM	17 Minutes	0,42 Second	0,47 Second	More Dijkstra Efficiency

C. System Desaign

Flowchart or flow chart is a chart (chart) that shows the flow (flow) in the program or system procedure logically. The types of flowcharts used are flowchart systems and flowchart programs. The flowchart system is a chart that shows the overall work flow of the system[16], [17], [18].

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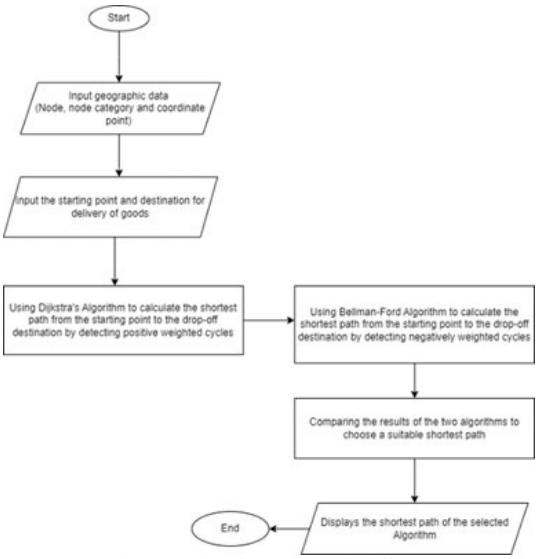

Figure 3 Flowchart of Goods delivery

Use cases are a high-level model of system requirements. Use case diagrams are primarily used to visualize use cases, related sectors, and their interactions, Use cases can describe the type of interaction between the system user and the system.[19], [20].

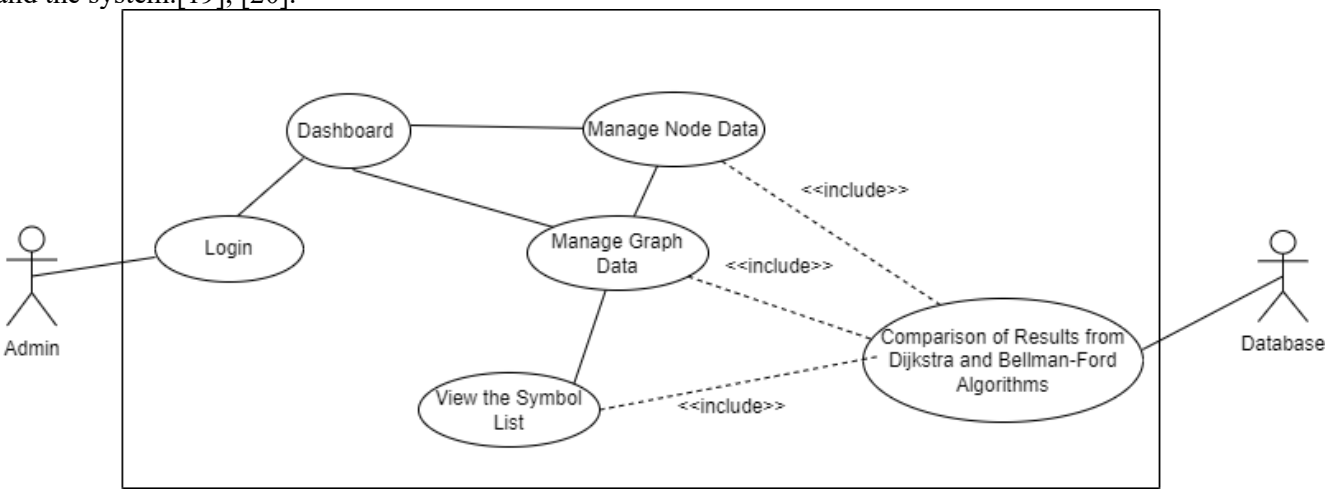

Figure 4 Use Case

Activity Diagrams are a technique for describing procedural logic, business processes and workflows in many cases. Activity diagrams have a role like flowcharts, but the difference with flowcharts is that activity diagrams can support parallel behavior while flowcharts cannot[21]

D. Application

This page is the main page when the user opens the goods delivery system. This login page is the initial display when this application is run. So that users must log in first then can enter the main page, the login menu is also used as monitoring of stored data. the login menu display consists of username, password input, and the sign in button functions to enter the system. Dashboard is the initial page when the admin successfully logs in. This page displays information about the J&T Tondo branch office in Palu City. On the right side of the page there are node data pages, graph data, symbol lists and admin data.

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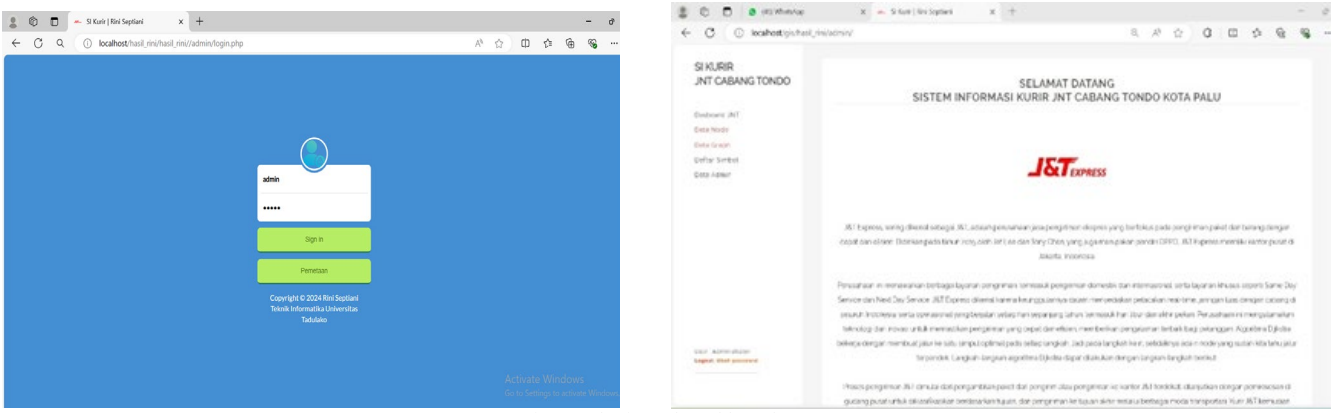

Figure 5 login and Dashboard Page

This Node Data page is a display for inputting or editing overall data. Admin is in charge of entering registered office data. Admins can also delete and change office or delivery location data via the buttons provided.

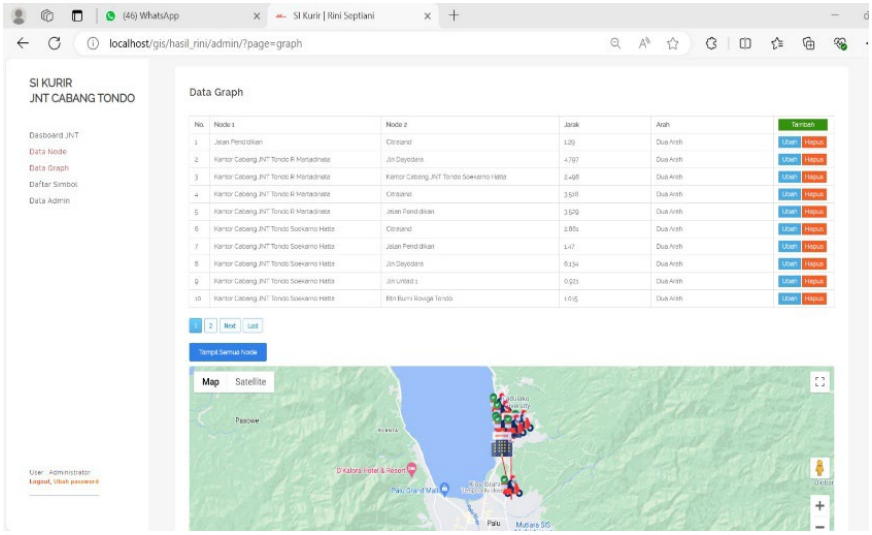

Figure 6 Node Data page

This Graph Data page is a display for inputting or editing overall data. The admin is in charge of entering office data that has been inputted in the data node then the admin inputs the delivery route from the office location that has been inputted to the delivery location. Admins can also delete and change office or delivery location data via the buttons provided.

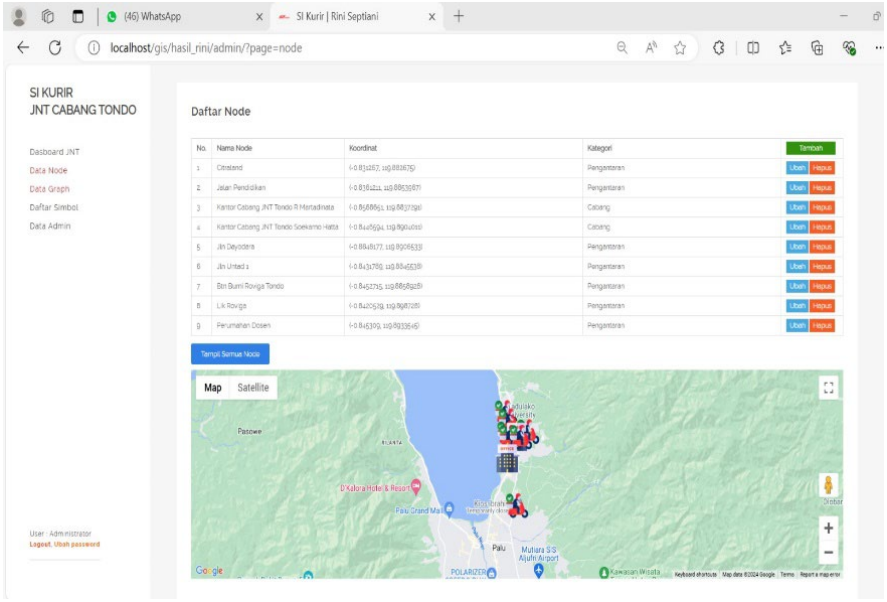

Figure 7 Graph Data Page

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The node category data page contains a notification of the symbol description used in this goods delivery system.

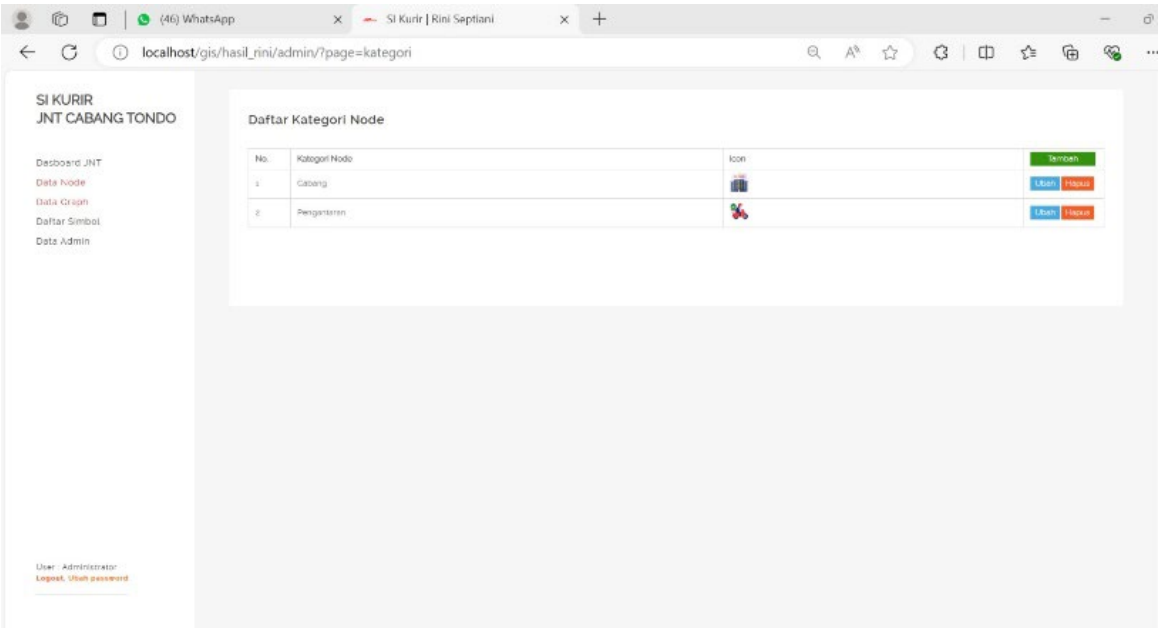

Figure 8 symbol Category List page

On this page the admin enters the delivery path by entering the data that has been inputted previously then the admin chooses the algorithm that is available and compares the two algorithms in order to get more efficient results.

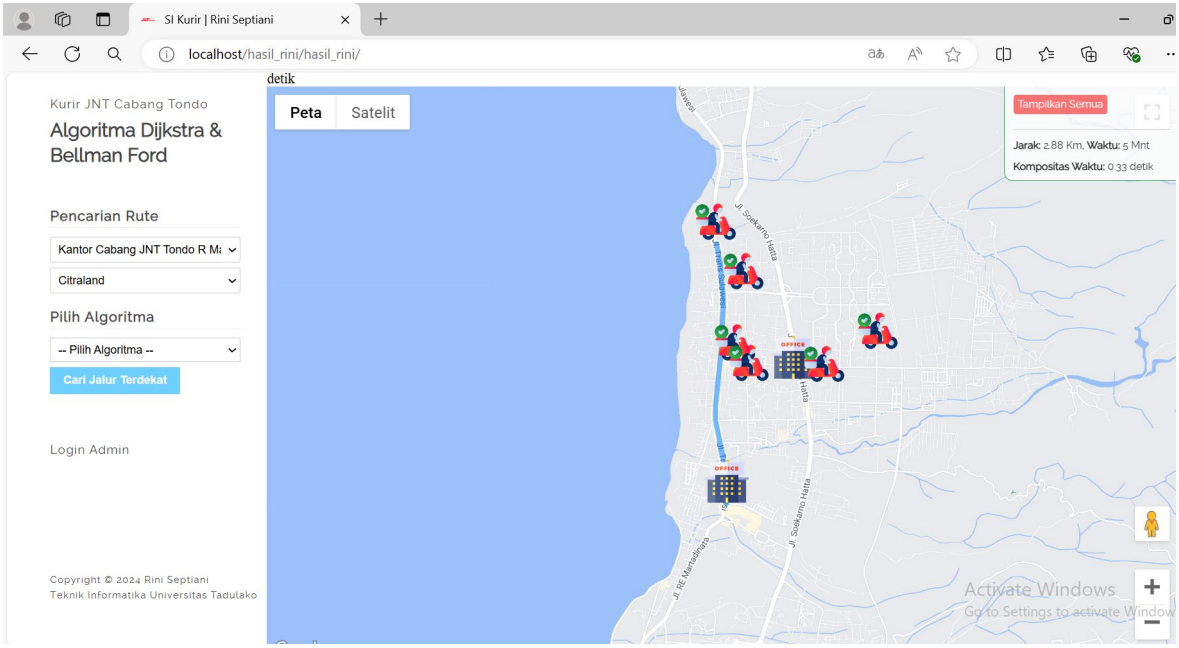

Figure 9 Dijkstra and Bellman-Ford Algorithm Comparison Page

E. Blackbox

Black-box testing is a software testing method that tests the functionality of an application or system. The Black-box method focuses on the functional requirements needed by the software. Black-Box testing is a test that focuses on the functional specifications of the software, the tester can define a set of input conditions and test the functional specifications of the program[22]

TABLE 2
SYSTEM TESTING PAGE

Test Case	Test Scenario	Testing Results
Opening the website	Open the website address	Valid
login	Enter the username and passsword according to the database then press the login button	Valid
View node data	Pressing the node data button on the left sidebar	Valid
Add node data	Add node data and press the save button	Valid
Change node data	Modify the contents of the selected node data and press the save button.	Valid
Delete node data	Press the delete button on one of the data nodes, then press the OK button	Valid
View graph data	Pressing the graph data button on the left sidebar	Valid
Add graph data	Add the node data and press the save button	Valid
Changing graph data	Modify the contents of the selected graph data, then press the save button	Valid
Delete graph data	Press the delete button on one of the graph data, then press the OK button	Valid

IV. CONCLUSION

The conclusion of this research is that the search for shortest paths for delivery of goods uses Bellman-Ford and Dijkstra Algorithms in determining the shortest path for delivery of goods. this research compares two algorithms, namely bellman-ford and dijkstra. the results show that the dijkstra algorithm is more efficient in computational speed and is suitable for graphs with non-negative edge weights, while the bellman-ford algorithm is more flexible to handle graphs with negative edge weights although it requires longer computation time. The implementation of these algorithms in GIS is able to improve the efficiency of goods delivery by reducing travel time and cost through optimal paths. dijkstra is recommended for everyday use in the case of delivery with non-negative edge weights, while Bellman-Ford is relevant for special situations involving negative edge weights or negative cycle detection, thus making a significant contribution in the field of logistics

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