Jurnal Informasi dan Teknologi
https://jidt.org/jidt
2024 Vol. 6 No. 1 Page: 138-143 e-ISSN: 2714-9730

Implementation of Rapid Application Development Method for Designing a Decision Support System to Reduce a Congestion Through Reversal Layout Engineering

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Abstract

This research aims to produce a decision support system to reduce traffic jams through U-turn layout engineering. We carried out data collection by recording traffic at the research site and conducting interviews through questionnaires submitted to the sources. System development stage, where this stage is divided into three major stages according to the method used, namely the RAD method. The three major stages are requirements planning, workshop design, and implementation. Based on the research results, it was found that the modeling of traffic passed by a U-turn can be identified through calculation graphs of volume, speed, density, capacity, degree of saturation, and geometric delay. Traffic flow engineering is implemented by modeling eight open U-turns, which are then eliminated or closed one by one in order to increase vehicle speed and reduce delays on that road section. We also carried out contraflow modeling for comparison. However, the results obtained were no better than U-turn elimination. The largest average number of motorbikes at the end of the week was only 300 motorbikes on Saturday. Meanwhile, the largest average of motorbikes on weekdays was 400 motorbikes on Thursday. The design combines two WFA methods and the fuzzy logic method to present several alternative decisions in the form of final values and bar graphs. These alternatives can be used as material for expert consideration in decision-making. A graph can serve as a benchmark when eliminating U-turns and testing contraflow on the road. Eliminating U-turns and testing contraflow on the road can provide an alternative decision solution using the largest graph.

Keywords: Decision Support Systems, Traffic Congestion, U-Turn, Contraflow, Fuzzy Logic.

1. Introduction

Traffic engineering improves conditions and addresses problems that arise from new traffic facilities. The primary goal is to ensure that the facility is well designed, safe, and adequate for use. One important research motivation was to test the effectiveness of existing u-turn layout engineering [1]. The research team must objectively choose and implement the traffic engineering implementation strategy in the previous modeling stage to achieve this goal. The first step of this research involves evaluating and testing the implemented u-turn layout engineering. Modeling methods involving calculation graphs of volume, speed, density, capacity, degree of saturation, and geometric delay will be the basis for understanding the ongoing traffic situation. Furthermore, the chosen engineering strategy should include an in-depth analysis of the performance of the u-turn layout. The use of quality outdoor tools or equipment is the key to obtaining accurate field data. The results of this testing will be the basis for assessing the success or failure of existing engineering [2]. In addition, this approach pays attention to security aspects in designing traffic facilities. Thorough risk and accident evaluations are necessary to ensure that the u-turn layout engineering improves traffic efficiency and provides a safe environment for road users. Overall, an objective traffic engineering approach based on prior modeling will ensure that the proposed solutions are not only effective in addressing the existing problem but also meet the safety standards required in the design of traffic facilities [3].

Decision support systems (DSS) as part of the information systems science domain play a very important role in solving transportation problems on highways, especially those that have a direct impact on congestion. The efficacy, efficiency, and effort level of DSS, as perceived by users, are important factors that impact their incentive to use the system. User motivation to use DSS and perception of it are predicted to be positively correlated [4]. When users believe that DSS is more efficient, effective, and user-friendly, their motivation to utilize it tends to rise. While a small amount of study continues to look at how user attributes may affect how DSSs are perceived, many studies have concentrated on assessing the effectiveness of DSSs. Individuals may be

Receipt: 18-01-2024 | Revision: 20-01-2024 | Publish: 27-01-2024 | doi: 10.60083/jidt.v6i1.487

encouraged to emphasize the effectiveness of the DSS more when considering factors that are deemed significant in the decision-making process [5]. When users see how the DSS's choice alternatives help them achieve their goals, they could also be more motivated to work harder to get there. Therefore, user consideration in making decisions can lead to increasing the effectiveness of using DSS in overcoming transportation problems on the highway [6].

A basic understanding of decision-making is that it involves selecting one option from a range of options. Creating alternatives entails creating a long list of possibilities based on a problem statement, which is a slightly more complex perspective [7]. Finding opportunities to make decisions entails realizing that decisions need to be made. When faced with an obvious decision, a firm management may have to make it (the choice of supplier from all accessible suppliers). Managers who effectively define challenges are able to make innovative design choices, like choosing how to promote a new product, that optimize earnings. Lastly, by researching the business's activities and the external environment, the manager can proactively spot chances. For example, they can look for methods to improve the productivity of the production process [8]. The final choice quality is determined by how decision problems are structured and what innovative alternatives are found, according to numerous anecdotes and some actual data. Massive decision-making is the primary goal of DSS. Apart from providing support for decisions, DSS also helps with system modeling and analysis (for complex organizations), opportunity identification, and problem structuring [9].

A collection of interdependent subsystems functions as a cohesive unit to form an entity known as an information system. These subsystems work together and interact in specific ways to perform data processing tasks. Its duties include taking in data as input, processing it, and then generating information as output. This system generates data that is useful for making decisions, has genuine worth, and will benefit society in the long run. This information system aims to support operational activities by utilizing various existing resources so that it can achieve a desired goal [10]. We will implement business processes as the core of operational activities. Information systems have an important role in ensuring that business processes can run efficiently, effectively, and as desired. Apart from that, information systems also play a role in integration with many business processes. This integration aims to gain competitive advantages in the business environment [11]. With a well-integrated information system, companies can increase their competitiveness, optimize the use of resources, and achieve competitive advantage. Thus, information systems are not only a tool to support business processes but also a key factor in achieving company goals and facing competitive challenges in the business world. Along with the development of information technology, the role of information systems becomes increasingly crucial in maintaining the continuity and success of an organization [11].

Traffic can be defined as the movement of pedestrians and goods along a route. A major challenge for traffic engineers is the frequent imbalance between traffic volume and route capacity, resulting in congestion. The phenomenon of traffic jams is not new, as recorded in Roman history, where Roman roads were often clogged with traffic. In fact, an emperor once issued a proclamation threatening the death penalty for those who blocked the road with their chariots or carts [12]. Traffic does not only refer to motorized vehicles but also includes the transportation of goods and the movement of people through various modes such as road, rail, and air. However, sometimes, in everyday use, the word "traffic" is often associated with motorized vehicles, while pedestrians and cyclists are ignored. In the context of traffic engineering, the focus is broader, encompassing the design of facilities for various forms of road traffic [13]. Therefore, traffic engineering does not only relate to motorized vehicles but also involves pedestrians, cyclists, and various types of traffic, including two-wheeled vehicles, cars, buses, trams, and other commercial vehicles. By understanding this broader definition, traffic engineering aims to design adequate facilities for all types of traffic, thereby optimizing movement and preventing congestion [13].

One of the most frequently encountered turning facilities is the u-turn. This facility is a special place for motorized and non-motorized vehicles to rotate and is used on road sections with dividers. In order to maintain the overall level of road service in U-turn areas, it is necessary to take into account the proportional capacity of the road that is disrupted due to a number of traffic flows making U-turn movements [13]. The median facility, which is a separation area between traffic flow vehicles and reverse flow vehicles, is adjusted to traffic conditions, road geometric conditions, and traffic flow composition. Contraflow vehicle lanes allow vehicles to avoid circuitous routes [14]. The main disadvantage of continuous contraflow vehicle lanes is that they prevent curbside access by vehicles (half of the road is unusable), such as vehicles carrying heavy goods, which are not permitted to use them [15] [16][17][18]. A common method of overcoming this drawback, especially when the vehicle contraflow lane will last a long time, is to use a closure point for all vehicles except the contraflow vehicle and then allow other vehicles access from side roads along the contraflow road.

2. Research Methods

In conducting research, the stages of research activities follow a research methodology, which can be explained by the fact that research is carried out through four stages. During the initial analysis stage, researchers collect literature studies and pre-analysis. The second stage is situation analysis, where observation and data collection are carried out. Data collection was carried out by recording traffic at the research site and conducting interviews by submitting questionnaires to the sources. We conducted data collection using research methods. The system development stage is divided into three major stages according to the method used, namely the RAD method. The three major stages are requirements planning, which consists of data analysis and system analysis. Design workshop consisting of system design, database design, and interface design. For the optimization stage, the methods used are the WFA method and the fuzzy logic optimization method. Lastly, the system development stage is implementation, which consists of the coding, verification, and model validation stages. After the system development stage is complete, the next and final stage is reporting.

3. Results and Discussion

Analysis of traffic flow data at the research location from Monday to Friday highlights the dominance of motorcycles as the most common vehicles passing through. Peak motorbike activity occurs on weekdays, especially on Thursdays, with the number reaching 400 motorbikes in a 5-minute period. In contrast, on weekends, especially Saturdays, the number of motorbikes passing reached a peak of only 300 motorbikes. This comparison confirms that motorbike frequency is higher on weekdays compared to weekends. The difference in the number of motorcycles between weekdays and weekends reached 200 motorcycles, indicating the high intensity of traffic on weekdays, especially on Thursdays. This data is an important key for traffic planning and transportation management. Understanding the different traffic patterns between weekdays and weekends provides a basis for developing more effective strategies and policies. By utilizing this information, decision-makers can design appropriate solutions to optimize traffic flow and reduce congestion, especially on days with high traffic volume levels. This data is an important instrument for improving the efficiency and sustainability of the transportation system at the research location.

Two main functions support the decision-making process in traffic engineering: traffic modeling based on weighted factor analysis (WFA) and optimization, which utilizes two methods WFA and fuzzy logic. These functions aim to create effective decision-making alternatives for overcoming traffic jams. The main effort in this research is to identify optimal solutions to eliminate or at least reduce traffic jams that often occur. Three core parameters, namely geometry delay, traffic density, and saturation degree, greatly influence traffic speed, which is a key variable in this decision-making process. These parameters have a crucial role in shaping traffic speed, which in turn influences the level of congestion. The optimization process focuses on adjusting and managing these parameters. The main objective of this research is to create appropriate and effective decision alternatives through an optimization process using the WFA and fuzzy logic methods. This approach aims to achieve a solution that significantly reduces traffic jams. By integrating traffic modeling and optimization techniques, this research seeks to contribute to the development of more adaptive and efficient traffic engineering strategies for dealing with road congestion problems.

The use case diagram generally illustrates that the creation of this system involves three main types of actors experts, local governments, and traffic MIS (traffic management information system). The single user who interacts directly with this system is the local government. The local government can carry out various interactions in this system, such as extracting data, parameterizing, optimizing, making decisions, and reporting. The first actor, Traffic MIS, functions as an external system that provides the necessary data but is not included in the system being created. The main task is to extract data from the traffic information it has. The second actor, the expert, has a role in parameterizing. The main task of the expert is to define the value weights needed to calculate alternative decision variables and carry out optimization. The expert obtained the weight values required for parameterizing through data extraction from traffic MIS. Local government, as the main user, can view traffic modeling through optimized data. In addition, local government has the ability to optimize water flow, eliminate U-turns, and test contraflow. Decisions are taken by the local government based on alternative decisions provided in the system. This system also provides facilities to access and view reporting results, which include traffic modeling and optimization. Through this facility, the local government can monitor the progress and results of decisions that have been taken. By paying attention to the interactions and roles of each actor, the use case diagram provides an overview of how this system works and interacts with users and external data sources.

Activity diagrams provide a detailed description of the sequence of activities in the system, especially in the context of extracting data. The actors will transfer data into the system database under construction. In the data extraction activity, the main focus is on the extract road traffic process, where the system will extract data from the traffic MIS. This step occurs through the extracting vehicles subprocess, which consists of three types of vehicles: light vehicles, heavy vehicles, and motorcycles. Each vehicle type will have specific information relevant to its characteristics and required traffic data. In the extract road traffic process, we will extract or load the data. This sub activity involves extracting data that is critical to traffic analysis, including extract volume, extract velocity, extract density, extract capacity, extract saturation degree, extract delay, and extract U-turn.

Each data element plays a role in presenting a complete picture of traffic conditions at the research location. With this activity diagram, you can clearly understand the sequence of steps in the data extraction process and how the system manages information from traffic MIS and then loads it into the database. Additionally, these diagrams help visualize the relationships between the various subprocesses involved, providing a holistic view of the system's workflow in collecting the necessary traffic data.

Sequence diagrams provide illustrations of interactions between operations in system processes, especially in data-extracting sequence diagrams, which show the attributes used in each operation, as explained in the previous activity diagram. To carry out the data extraction operation in this sequence diagram, it is necessary to identify a number of attributes. Nine operations are involved in the data extraction process, with each operation represented by an arrow symbol pointing to the right. When executed, each operation provides feedback on the required attributes. Traffic MIS carries out the data extraction process through nine operations, traffic road, vehicle, road volume, road velocity, road density, road capacity, road saturation degree, geometry, road delay, and U-turn. Each operation has a specific role in collecting traffic data from different sources. In this context, the attributes used include information about road conditions, types of vehicles, as well as specific data related to volume, speed, density, capacity, degree of saturation, delays, and U-turns (road volume, road velocity, road density, road capacity, road saturation degree, geometry, road delay, and U-turn). By presenting the interactions of these operations in sequence form, this diagram provides a more detailed and dynamic picture of how each operation interacts with each other and contributes to the overall process of extracting traffic data.

The class diagram represents the decision support system for overcoming traffic jams through vehicle U-turn layout engineering. This class diagram provides a detailed description of the structure of the classes in the system. The main class that is dominant in this diagram is the traffic road, which represents the primary element of the research traffic road. The vehicle class aggregates the traffic road class and functions as a container for storing vehicle data recorded every 5 minutes for 1 hour via video recording. The light vehicle, heavy vehicle, and motorcycle classes are subclasses or generalizations of the vehicle class, representing the types of vehicles that may pass. Next, there is the U-turn class, which is responsible for recording the number of U-turns that occur at the research location. The U-turn class records the number of U-turns that occur at the research location, while road volume calculates the volume of traffic on a road, road velocity calculates speed, and road density measures density on a road. Road capacity reflects the capacity of the road, while road saturation degree calculates the level of saturation on the road. The geometry road delay class plays a role in calculating geometric delays on the road. To carry out this calculation, it is necessary to involve the queue length class and the stopped vehicle class as part of the process. By combining these classes in a class diagram, the system can efficiently manage and analyze traffic data, thereby supporting decision-making regarding vehicle U-turn layout engineering. This diagram provides a clear and systematic representation of how classes relate to each other and contribute to developing solutions to reduce congestion on the road.

Several classes closely relate to the traffic road class in the class diagram structure. The day class differentiates the day and time when traffic data is recorded by aggregating it with the time class. The decision class represents the decision-making process, and part of this class is the best decision alternatives class, which functions as a container for storing the final value of the optimization process. Furthermore, the fuzzy waterflow optimizing class has a special role in the optimization process. This class contains the parameters and operations required to perform fuzzy optimization. This class also aggregates classes called membership functions and limit values to support fuzzy optimization. Membership functions and limit values provide an important contribution to organizing the fuzzy optimization process by providing the necessary limits and membership functions. Each class in this diagram has a specified multiplicity, with most having a one-to-one relationship, except for the relationship between the traffic road and U-turn classes, which are one-to-many, and the day and time classes, which are also one-to-many. These relationships reflect the different relationships between the classes, and multiplicity indicates the number of objects involved in each relationship. With a well-organized class structure and clear relationships, the system can efficiently manage traffic information, make decisions, and carry out fuzzy optimization processes. This class diagram provides a holistic view of the structure and relationships between classes in a decision support system to reduce congestion through vehicle U-turn layout engineering.

Database mapping is an important process in converting a MySQL database design into a relational management database system format. The main function of a database is to store data required by a system. We created 11 tables to accommodate various relevant information for the decision support system aimed at overcoming traffic jams through U-turn layout engineering. These tables involve various data aspects such as road conditions, recording time, road capacity, geometric delay, traffic volume, speed, density, saturation level, fuzzy parameters, and water flow optimization results. Each table has a specific purpose for storing and managing related data, creating an organized and efficient structure to support decision-making systems. The following is a list of the tables involved, namely tb_traffic_road, tb_hour, tb_date, tb_capacity, tb_delay, tb_volume, tb_velocity, tb_density, tb_saturation, tb_fuzzy, and tb_waterflow. Through these tables, the system can effectively access, manage, and analyze the data needed to support optimal decision-making in overcoming traffic congestion problems. With a planned database structure, the system can operate more efficiently and be responsive to changing traffic dynamics.

After the optimization process of traffic modeling, the optimization model describes the results obtained and presents the resulting findings. The research utilizes two different optimization methods: weighted fuzzy average (WFA) and fuzzy logic. The research tries to integrate these two methods into an approach called the fuzzy water flow algorithm (FWFA). The FWFA approach utilizes the WFA method to assign weights to certain variables involved in traffic modeling. Calculations and analysis will later utilize this weight to provide a final value for each decision alternative. Meanwhile, fuzzy logic is used to consider the uncertainty and complexity of traffic data, which may be difficult to measure precisely. By combining these two methods in FWFA, the research seeks to create a more holistic and accurate approach to decision-making related to traffic optimization. This model is expected to provide a better solution for overcoming congestion and improving traffic flow. Summarizing information from these two methods, FWFA is expected to positively contribute to the efficiency and effectiveness of decision support systems in managing traffic at the research location.

4. Conclusion

This research presents five conclusions obtained from traffic analysis. First, we identify key variables such as volume, speed, density, capacity, degree of saturation, and geometric delay to carry out traffic modeling. We analyze the collected data using the calculation graphic method. Second, we gradually close eight open U-turns on the road to carry out traffic flow engineering, comparing it with contraflow modeling. The results show that U-turn elimination provides better vehicle speed improvement and delay reduction than contraflow. Third, observation data revealed significant differences in the number of motorbikes passing through the research location between weekdays and weekends, with Thursday being the busiest day. Fourth, the decision support system design combines the weighted factor analysis method and fuzzy logic, producing alternative decisions that can be considered by experts. Fifth, the graph of the results of the U-turn elimination experiment and contraflow testing provides guidance for decision-making, showing that U-turn elimination can increase traffic speed by 4 km/h. The largest graph of U-turn and contraflow elimination is a potential solution to increase traffic efficiency.

Future research in the road sector can be divided into three main aspects. The main obstacle to this research is the limitations of the tools or equipment used. Therefore, researchers should use tools or equipment with adequate outdoor quality to enhance the effectiveness and accuracy of field research. Second, in identifying research objects, there are various interesting potentials, especially in the road sector. One interesting research object is to investigate the extent of illegal collection by government services on the roads. Furthermore, the design of the flyover on the road and the efforts to control the road, particularly in relation to street vendors in the campus area, are also intriguing subjects for further investigation. Third, experts, especially the department of transportation, state that constructing flyovers along the road is the solution to overcoming traffic congestion. Experts, especially the department of transportation, state that constructing flyovers along the road can effectively increase road capacity and reduce traffic density by dividing vehicle speeds into several lanes. This suggestion can be the focus of further research to explore potential infrastructure solutions that can be implemented to mitigate traffic problems on highways.

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