Journal of Infrastructure, Policy and Development 2024, 8(5), 3175.
https://doi.org/10.24294/jipd.v8i5.3175

Article

Redesign roadmap to support driving awareness at level railway crossings

Sugiono Sugiono[1,*], Evan Wiryawan[2], Bayu Rahayudi[3], Angga Akbar Fanani[1], Maulana Ahmad Fahreza[1], Addis Rheza Firmansyah[1], Wahono Hadi Sucipto[1], Fa'iqul Marom[1]

[1] Department of Industrial Engineering, Universitas Brawijaya, Jawa Timur 65145, Indonesia
[2] PT. Inka, Madiun 63115, Indonesia
[3] Department of Computer, Universitas Brawijaya, Jawa Timur 65145, Indonesia
*** Corresponding author:** Sugiono Sugiono, sugiono_ub@ub.ac.id

CITATION

Sugiono S, Wiryawan E, Rahayudi B, et al. (2024). Redesign roadmap to support driving awareness at level railway crossings. Journal of Infrastructure, Policy and Development. 8(5): 3175. https://doi.org/10.24294/jipd.v8i5.3175

ARTICLE INFO

Received: 6 November 2023
Accepted: 14 December 2023
Available online: 24 April 2024

Abstract: The number of accidents at level railway crossings, especially crossings without gate barriers/attendants, is still very high due to technical problems, driving culture, and human error. The aim of this research is to provide road maps application based on ergonomic visual displays design that can increase awareness level for drivers before crossing railway crossings. The double awareness driving (DAD) map information system was built based on the waterfall method, which has 4 steps: defining requirements, system and software design, unit testing, and implementation. User needs to include origin-destination location, geolocation, distance & travel time, directions, crossing information, and crossing notifications. The DAD map application was tested using a usability test to determine the ease of using the application used the System Usability Scale (SUS) questionnaire and an Electroencephalogram (EEG) test to determine the increase in concentration in drivers before and immediately crossing a railway crossing. Periodically, the application provides information on the driving zone being passed; green zone for driving distances > 500 m to the crossing, the yellow zone for distances 500m to 100m, and the red zone for distances < 100 m. The DAD map also provides information on the position and speed of the nearest train that will cross the railway crossing. The usability test for 10 respondents giving SUS score = 97.5 (satisfaction category) with a time-based efficiency value = 0.29 goals/s, error rate = 0%, and a success rate of 93.33%. The cognitive ergonomic testing via Electroencephalogram (EEG) produced a focus level of 21.66%. Based on the results of DAD map testing can be implemented to improve the safety of level railroad crossings in an effort to reduce the number of driving accidents.

Keywords: railroad crossings; roadmap; EEG; System Usability Scale (SUS); Python; driving awareness

1. Introduction

The number of traffic accidents at railway crossings is still quite high, especially at crossings without guards/doorstops (Hong et al., 2023; Johnson, 2015). Accidents at railway crossings occur not only in Indonesia or other developing countries but also in developed countries. During the last 10 years, there were 3427 accidents at private crossings, or around 14% of the total USA national accidents (Anderson, 2023). Therefore, there has been a lot of research on it globally. Wise words say that to cross a train, all riders must use three words: stop, look, and listen. The costs of losses due to accidents at railway crossings divided into those due to productivity, quality of life costs, medical costs, long-term maintenance costs, property damage, insurance costs, and police costs.

The main causes of accidents at level crossings are driver behaviour that lacks discipline and the large number of unofficial level crossings. Dezhkam and Eslami (2017) and Gemma et al. (2021) state that the causes of accidents include: rail factors, road factors, environmental factors, human factors, and crossing factors. Many methods have been used to prevent or reduce accidents, namely: building crossings (Mironer et al., 2000), traffic control devices (Park et al., 2021; Saccomanno et al., 2017), geometry in the form of improving the condition of pavement (Caird et al., 2005), posted speed limits (Saccomanno et al., 2017), and photo/video enforcement (Caird et al., 2005). Hogan et al. (2017) said that upgrading railway crossings using flashing lights requires large funds. In the future, when solving railway crossing problems, it will be necessary to pay attention to the risk level of each location (Kasalica et al., 2020). Teresa and Wieslaw (2021) conducted research by detecting obstacles around crossings using deep learning.

The adoption of the 5.0 social system is urgently needed to realize driving awareness so that the value awareness of all parties becomes better by using technology and information systems. Actors at railroad crossings, both road drivers, engineers, and field officers, must work well together through an efficient and targeted system. The initial stage of the solution design is to provide a road map like on a Google Map for motorists who have features that are able to provide early alarms for motorists to pay attention, monitor, and focus on the fact that they will soon be crossing a railroad crossing. This road map is the answer to the high accident rate for motorists at railroad crossings caused by a lack of awareness. Many people have measured the level of awareness, such as: Hofbauer et al. (2020) measured the level of driver awareness with Region-of-Interest prediction and eye tracking, Gilad and Borowsky (2015) measure and train hazard awareness in drivers, and Qimbiao et al. (2023) research on situational awareness related to different workloads using Electroencephalogram (EEG) and eye tracking features in air traffic control tasks. Furthermore, the information system application is also very important to measure the usability test, which includes learnability rate, efficiency, error, and System Usability Scale (SUS).

2. Research materials

An accident is a very complex event, because it can have many causal factors, a traffic accident can come from humans, machines, vehicles, roads, and the environment. Human factors are influenced by drivers, passengers, and road use; vehicle factors are influenced by non-motorized vehicles and motorized vehicles. Road factors are influenced by the goodness of the road and road facilities, and environmental factors are influenced by weather and geography. A traffic accident is a failure in the performance of one or more driver components that results in death, serious injury, and/or property damage. Road and ordinary road accidents can be categorized into at least four categories, including consecutive accidents, single accidents, pedestrian accidents, and stationary object accidents (Guo et al., 2018). In general, train accidents at crossings are caused by human negligence, whether from crossing officers, or drivers themselves (Li et al., 2019; Rangra et al., 2015). Rail transport has many entities that all contribute to a safe and efficient transportation system. It consists of several human actors (driver, signalman, maintenance personnel, and operational management) and a signaling system that works in a synchronized manner (Evans, 2011).

Researchers reported that human factors, such as age and gender, have an impact on driving (Bao et al., 2020). Sagberg et al. (2015) identified age, gender, national, and regional differences that influence driver behaviour. Additionally, researchers found that driving on active workdays may have a negative impact on driving safety because drivers are under enormous pressure to get to work (Ghasemzadeh and Ahmed, 2019). Zhang et al. (2019) meta-analysis shows that human-machine interaction providing a combination of visual and auditory or tactile information enables a reduction in travel time in vehicles. Traffic accidents can be reduced or avoided by increasing the awareness of drivers, officers, or the public involved. Situational awareness will be the basis for making good decisions, especially on complex and dynamic system issues. There is empirical evidence that the situation awareness model is relevant in driving contexts that affect driving performance (Endsley, 2017). A driver who experiences decreased situation awareness may fail to understand information or elements while driving. **Figure 1** below explains how good driving performance can be achieved by paying attention to supporting factors such as task, personal, and situational awareness factors.

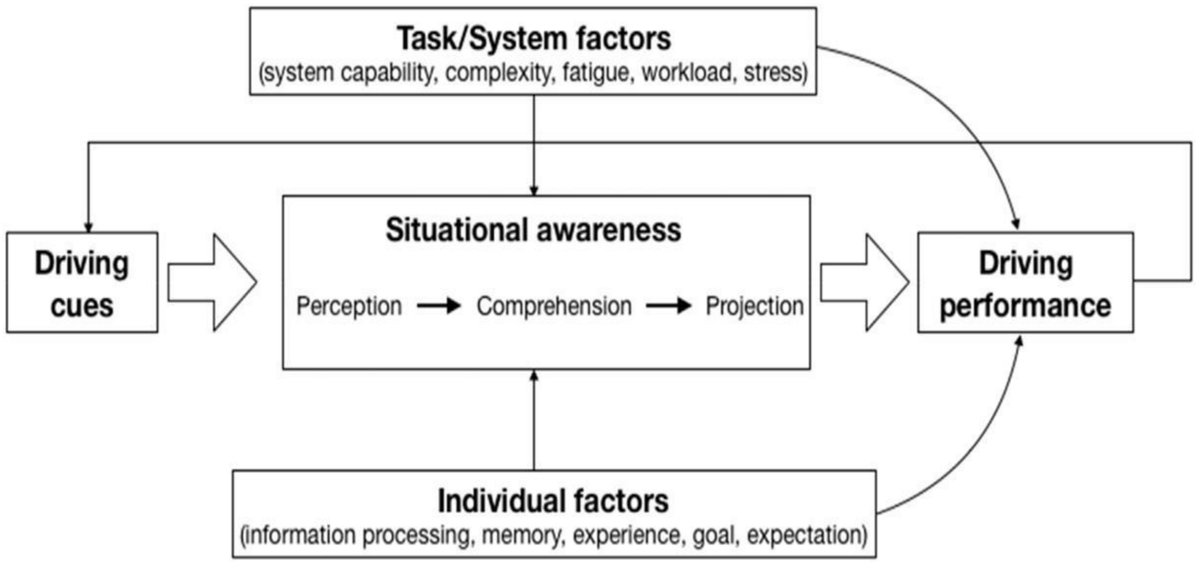


Figure 1. The modified Endsley's concept of situation awareness in the driving context (Wijayanto et al., 2021).

The roadmap application is part of the product that relates to the interaction between humans and machines, so the resulting product or application needs to be tested for ease of use. Usability research in the field of transportation has been carried out in order to improve the performance of service users (passengers). Hussain and Mkpojiogu (2016) presented the results based on the results of a review of 144 papers, showing satisfaction, effectiveness, and efficiency were the most frequently used metrics. Meanwhile, surveys seem to be the most popular method among researchers, followed by field trials and interviews. Widyanti and Qurratu (2017) said that one of the most important components of online transportation is the user interface application. The concept of usability is often associated with user-friendliness, human-computer interaction (HCI), human-computer interaction (CHI), user-centered design (UCD) and so on. Usability is user convenience with goals to be achieved, namely ease of use, efficiency, low error, and user satisfaction when using a product or system.

User interface (UI) is a term used to describe the appearance of a machine or computer that the user directly interacts with. The design and arrangement of the interface need attention to produce a good display. Schlatter and Levinson (2013) arranges an easy-to-use application design by dividing it into several influential components: consistency, hierarchy, personality, layout, type, color, image, control, and affordability. Usability is defined in International Organization of Standardization (ISO) 9241-11 as the level of user satisfaction, as well as the effectiveness and efficiency of a product for certain purposes. To evaluate usability, product effectiveness is measured based on use for specific purposes and the achievement of integrated system functions. On the other hand, efficiency is evaluated by measuring the resources expended to achieve proper use and integrity. While, satisfaction refers to the comfort and aesthetic value of the user. The usability dimension needs to cover five things: learnability, efficiency, recall, error, and satisfaction.

Usability testing is used to calculate learning ability, efficiency, and error components. While the questionnaire data is used to calculate the satisfaction component. The learning ability component is calculated using the success rate, namely the percentage of tasks that the user completes correctly. Equation (1) is the equation used to calculate the level of ease, requiring the number of full successes (S), partial successes (P), and the total number of tasks given (Nielsen, 1993).

$$Success\ Rate = \frac{(S + (P \times 0.5))}{Total\ Task} \times 100\% \tag{1}$$

The efficiency component is calculated using time-based efficiency, namely the time it takes the user to complete a task. Equation (2) is the equation used to calculate the time needed to complete a task (Nielsen, 1993).

$$Task\ time = End\ time - Start\ time \tag{2}$$

Efficiency is calculated by all relative efficiencies, using the ratio of the time required for a user to successfully complete a task and the time spent by all users. Equation (3) is an equation for calculating overall relative efficiency, which requires the number of tasks completed (N), the time spent on the task (t) and the number of test takers (R) (Nielsen, 1993).

$$Time\ Based\ Efficiency = \frac{\sum_{j=1}^{R} \sum_{i=1}^{N} \frac{n_{ij}}{t_{ij}}}{NR} \tag{3}$$

The error component is calculated using the error rate. Errors are defined as unwanted or unintentional actions, mistakes, errors, or omissions by the user in completing a task. Equation (4) is the equation used to calculate the error rate (Nielsen, 1993).

$$Error\ Rate = \frac{Total\ Defects}{Total\ Opportunities} \tag{4}$$

The satisfaction component is calculated using the SUS questionnaire score. Equation (5) is the equation used to calculate the level of satisfaction (Tuwanakotta and Tanaamah, 2022).

$$Score = (Q1 - 1) + (5 - Q2) + \cdots \times 2.5 \quad (5)$$

The System Usability Scale (SUS) is one of the most popular usability testing tools and is a method used to quickly and easily measure usability. SUS has 10 questions that users must answer after using the system to evaluate it, such as "I think I will use this feature, I think this feature is not complicated", and other questions. The SUS method uses a Likert scale (0 to 5) which can indicate the user's opinion of the system, ranging from strongly disagreeing to strongly agreeing. The following is an instrument about SUS. After the questionnaire data is collected, the respondents' responses are then converted into SUS values according to the predetermined stages. From these results, the average value of all respondents' assessment scores will be obtained. There are three ways to determine the value of the assessment results: acceptance range, value scale, and subjective assessment. **Figure 1** shows the distribution of the three assessments along with the boundaries of each different class. For the value scale, Brooke (2022) further defines that *F* value < 50, *D* value ≥ 51 and < 68, *C* value ≥ 68 and < 74, *B* value ≥ 74 and < 80.3, and *A* value ≥ 80.3.

3. Research methodology

The research aims to produce a road map that can increase the awareness of motorists who will cross railway crossings. Awareness can be increased by understanding the road map that will be traversed and the driver's concentration level. Apart from that, a good road map will provide early warning to drivers in the form of a more interactive road map. The research design involves information on the driver's position along with the estimated time to reach the crossing, information on the train crossing, and information on the nearest train that will pass along with the estimated time to cross the railroad crossing. The visual road map display includes dynamic railroad track images and audio early warnings for drivers. The visual road map display will be designed based on an ergonomic approach, including a human machine interaction scientific approach. System Development Life Cycle-Based Design with an Agile Model with frequent changes required and a small project size.

The steps in completing research to create interactive road maps for drivers to increase awareness include:

- A preliminary survey on the causes of train accidents at several level crossings, especially at crossings without officers. There are about 33% of railroad crossings in Indonesia that have no doorstops, which contributes to many accidents.
- Arrange the visual display algorithm in Google Maps.
- Designing a Google Maps visual display based on an ergonomics approach.
- Testing the finished road map at five train crossings with guards and 5 train crossings without guards, both with motorbikes and car drivers, in different conditions.

- Usability testing based on the System Usability Scale (SUS).
- Recommendations for improving the road map design, which is easier to use and can increase awareness.

Graphically, the research stages starting from data collection, road map prototype design, prototype testing, and improvement discussions can be seen in **Figure 2** below.

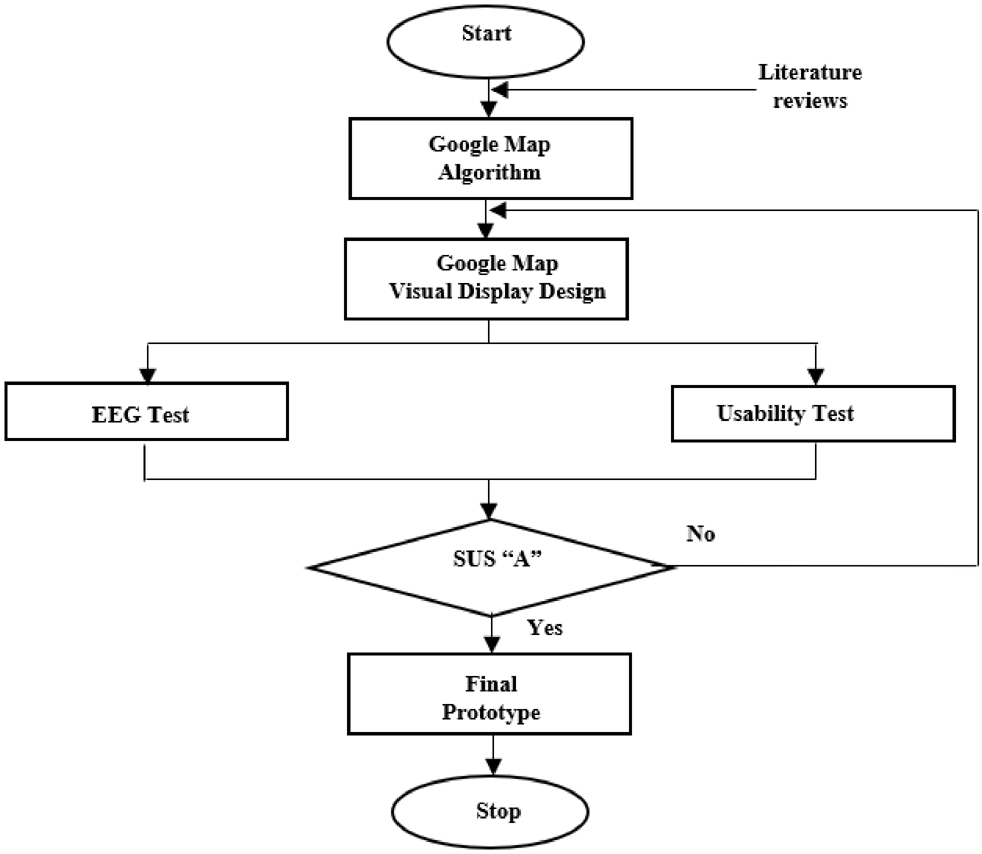


Figure 2. Flow diagram of research on creating "road maps" at railway crossings to increase driver awareness.

Usability tests use effective and limited respondents to get an overview of the design assessment desired by users. Nielson (1993) states the number of respondents' needs for usability tests in graphical form, where 6 respondents provide solutions to usability problems of around 85 percent and 15 respondents will provide nearly 100% solutions. Faulkner (2003) states that 5 respondents will generate an average of 85.55% usability problems, 15 respondents will generate 97.05% findings, 20 respondents will generate 98.4% problem findings, and 30 respondents will generate 99.0% problem findings. Thus, the number of respondents, amounting to 33 people, is sufficient to test the usefulness of the transportation network map on the Jakarta Mass Rapid Transport (MRT).

4. Results and discussions

Application of double awareness for systems at railway crossings, especially level crossings, without officers involving drivers and drivers. The current condition is that there are many railroad crossings without officers who do not have safety signs for crossings. Therefore, in order to realize the concept of double awareness, an information system has been built that will provide information in both directions, both to drivers regarding road conditions and also to drivers regarding the location of crossings and the position of trains that will pass. The information system will be able to keep drivers focused on the train track they are traveling on and also provide comprehensive information on the road situation at railway crossings. The double awareness information system was built based on the waterfall method, which has four steps: defining requirements, system and software design, implementation, and unit testing. The user (driver) needs information in the form of origin-destination location, geolocation, distance and travel time, directions, crossing information, and crossing notifications.

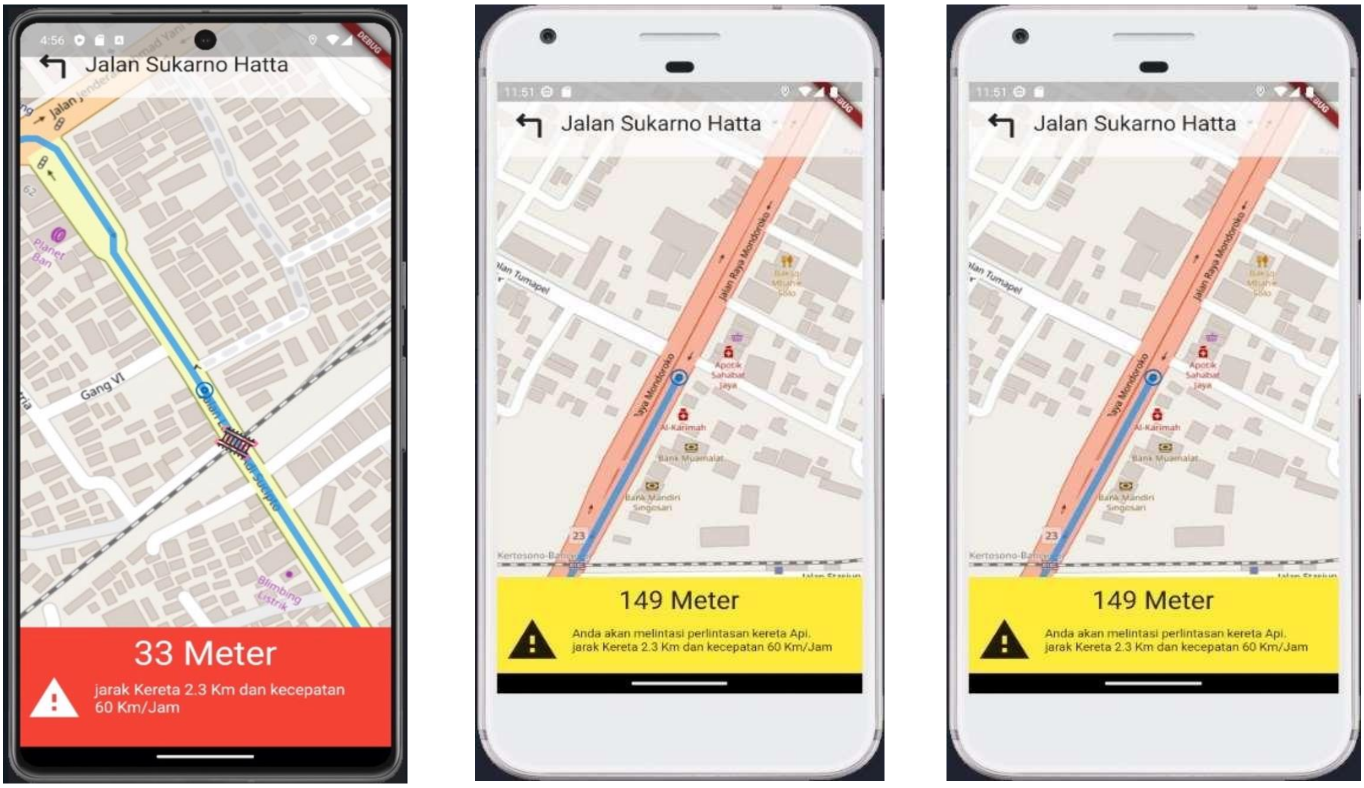
The next stage is system and software design. Process modelling is an activity to describe a business process or system in the form of a diagram or model that lists the flow of information, activities, and decisions during the process. At this stage, the system will be described following the algorithm that was built. After the driver activates the road map according to the specified destination, the map display in voice form will convey that during the journey he will pass through a certain number of railway crossings with or without officers. Drivers will be reminded periodically of the distance from the railway crossing, where distances of more than 1000 will be given a green signal on the screen, distances of 500m to 50m will be given a yellow warning with a sound, and distances of less than 50m will be given a red colour with an additional sound. When in the red zone application area, the road map also provides information about the location and speed of the train that will pass. Apart from that, in the red zone, the road screen display on the application layer will display quite striking railroad crossings (red colour with bold image).

The following is an example of the display used in building an information system algorithm for applying double awareness to drivers crossing railroad crossings, namely:

```
class _MyWidgetState extends State<MyWidget> {
AudioPlayer audioplayer = AudioPlayer();
List<Polyline> routepoint = [];
final mapcontrol = MapController();
LocationData? currentlocation;
LatLng? destinationpoint;
StreamSubscription<LocationData>? lokasi;
Marker? me;
List<Marker> displayedmarker = [];
String? timedestination = ‘‘, distancedestination = ‘‘;
List<LatLng>? coordinatedestination;
List<LatLng> coordinatesrailway = [];
bool railwaycomplete = false;
String statusrailway = “Red”;
int jarakrailwayterdekat = -1;
bool railwayvisible = false;
```

```
double previous_distance = 0;
double after_distance = 0;
```

The next stage is to build a user interface based on the algorithm that has been created. A user interface is a part of a software program that functions as a user communication path with a program by displaying a screen display to the user. In this research, the user interface was created using the Python programming language library, namely Tkinter, to facilitate user access to the program. The initial design of a road map application that comprehensively displays guidance for drivers to remain aware of level railroad crossings will look like **Figure 3** below.



(a) **(b)** **(c)**

Figure 3. Application of the double awareness information system for drivers who will cross a level railroad crossing, **(a)** rider position > 500 m; **(b)** rider's position between 500 m to 100 m; **(c)** rider position < 100 m.

An information system prototype application to support double awareness of drivers who will cross a railroad crossing in the form of an intelligent road map is tested for its ease of use through a usability test. For further studies, feedback from 10 respondents or users of roadmap information systems and supporting data are needed for the analysis process of these problems, including the level of ease of learning, the level of efficiency, the error rate, and the level of user satisfaction. In collecting quantitative data, there are 4 aspects that are measured: learnability, efficiency, errors, and satisfaction. From these 4 aspects, 4 data points were taken, namely the number of full and partial successes when the task is given to calculate the success rate on the learnability aspect, the time of completing the task for calculating time based efficiency on the efficiency aspect, total defects and total opportunities for calculating the error rate on the aspect errors, and System Usability Scale (SUS) questionnaire scores on the satisfaction aspect.

The learnability test was carried out on the road map application, which was tested by 10 respondents by carrying out 3 tasks, namely the task of knowing the number of crossings to be traversed (task 1), the task of knowing the red zone starts at –50 m (task 2), and the task of knowing the position of the train (task 3). **Table 1** shows the tabulation results of assignments to all respondents for three types of tasks. Based on the table, it can be concluded that the level of learnability of using road maps to increase the awareness of motorists who will cross the train can be categorized as good. Task 1 can be completed with a success percentage of 100%, task 2 is 80%, task 3 is 80%, and the overall average learnability level is 86.70%.

Table 1. Results of recapitulation of success in completing tasks by respondents using the railroad crossing roadmap application.

Respondents	**Task 1**	**Task 2**	**Task 3**	***Success Rate (%)***
R1	s	s	p	83.33
R2	s	s	s	100.00
R3	s	s	s	100.00
R4	s	p	s	83.33
R5	s	p	p	66.67
R6	s	s	s	100.00
R7	s	s	s	100.00
R8	s	s	s	100.00
R9	s	s	s	100.00
R10	s	s	s	100.00

The next assessment parameter related to the ease of use of the roadmap application to increase driver awareness when crossing railroad crossings is efficiency in carrying out tasks. Testing the value of efficiency is carried out by giving respondents two tasks, namely: preparing a road map according to a predetermined destination (task 1) and knowing the position of the train when drivers enter the red zone. **Table 2** explains the results of the time needed to complete tasks 1 and 2. Based on the table, it can be seen that the time-based efficiency of the first respondent is 0.22 and the average time for all respondents to complete the task is 0.29 goals/s.

Another measuring parameter is the level of errors experienced by users (respondents) in completing the task of using the roadmap to be more careful when crossing train crossings. Based on the simulation of the prototype, several potential errors were found that might be made by users, namely: 1. Mistakes in knowing the number of crossings to be passed, 2. Delays in knowing the red zone, and 3. Mistakes in knowing the position of the train when it is in the red zone. Meanwhile, in this test, respondents were given the task of using the application by passing through crossings with gate barriers/attendants and crossings without gate barriers/attendants. Based on the data summary, it was found that the average defect rate from respondents was 0 incidents, with a system testing error rate of 0% for 1 trip assignment and an identification of possible errors of 3 incidents.

Table 2. Task processing time in time-based efficiency calculations.

Respondent	Completing time		*Time based efficiency*
	Task 1	Task 2	
R1	9	3	0.22
R2	7	2	0.32
R3	8	2	0.31
R4	9	2	0.31
R5	9	4	0.18
R6	7	2	0.32
R7	8	2	0.31
R8	8	2	0.31
R9	7	2	0.32
R10	8	2	0.31

The System Usability Scale (SUS) is one of the most popular usability testing tools and a method that can be used to measure usability levels quickly and easily. SUS was developed by John Brooke in 1986. This SUS is the most widely used usability scale because it is easy to use, tends to reduce costs, and has a high level of reliability. SUS has 10 questions that users must answer after using the system to be evaluated. The SUS method uses a Likert scale, which can indicate the user's opinion of the system, ranging from strongly disagreeing to strongly agreeing. The following is the SUS question instrument. Based on the collection of data from 10 respondents, data were obtained on answers to 10 questions, as shown in **Table 3**. For example, respondent one gave a score on a Likert scale for 10 questions as follows, question 1 with a score of 5, question 2 with a score of 1, question 3 with a score of 4, and so on until question 10 with a score of 1.

Table 3. SUS question instrument.

No.	Questions	Score
1	I think I want to use this feature.	1–5
2	I found that this feature is not that complicated.	1–5
3	I think this feature is easy to use.	1–5
4	I think I need a technical person's help in using this feature.	1–5
5	I found the various functions in this feature well integrated.	1–5
6	I think there's too much inconsistency in this feature.	1–5
7	I would imagine that most people would find it easy to learn about this feature.	1–5
8	I find this feature very impractical.	1–5
9	I feel very confident in using this feature.	1–5
10	I need to learn a lot before using this feature.	1–5

After the questionnaire data given to respondents has been collected, the respondents' responses will then be converted to the SUS scale. The SUS scale is calculated by first calculating the Likert score for each respondent for odd questions (question no. 1, 3, 5, 7, 9) and subtracting the value 1. For example, respondent one has an odd score as follows:

Odd score = (Q1 − 1) + (Q3 − 1) + (Q5 – 1) + (Q5 – 1) + (Q9 − 1) = (5 – 1) + (4 – 1) + (4 – 1) + (5 – 1) + (4 – 1) = 17

Meanwhile, the SUS score for even questions is used to reduce the value of 5, so for example, respondent 1 will have an even score as follows:

Even score = (5 − Q2) + (5 − Q4) + (5 − Q6) + (5 − Q8) + (5 − Q10) = (5 – 1) + (5 – 1) + (5 – 1) + (5 – 1) + (5 − 1) = 20

So the SUS value for respondent 1 is the result of the number of odd scores plus the number of even scores multiplied by the value 2.5. So the SUS for the first respondent is:

SUS-R1 = (odd score+ even score) × 2.5 = (17 + 20) × 2.5 = 92.5

After each respondent's SUS value from 1 to 10 is calculated, the next step is to calculate the average SUS value and obtain a value of 97.5. This value based on the classification is included in grade A, the best performance. The road map information system application for driving safety that will cross railroad crossings is feasible to develop and use by users.

Recommendations for improving the double awareness application for drivers who will pass a level railroad crossing based on the results of the usability test are improving the red zone distance and improving the display of train position information by drivers. The red zone on the first design appearance appears when the distance of entering 50m from the railroad crossing point is felt by the respondents to be too close, so nine respondents suggested further testing at a distance of 100 m, and the results were very helpful for driver preparation. While the second recommendation appears in writing that informs the position of the train, it is felt by 7 respondents that the writing is too small to display on the mobile phone screen. The new design concept is improved by changing the size of the writing to be bigger and adding the audio of the position of the train.

After assessing the usability test, which reflects how well the human (user) interacts with the DAD application, it is necessary to know how much impact using the application has on the driver's concentration. It is hoped that the use of DAD can increase driver awareness by better understanding railway crossings. Carofiglio et al. (2019) define emotionality as a measure of how concentrated a person is in using a product/application to carry out their tasks or activities. Concentration assessment can be done by installing Electroencephalogram (EEG) equipment on several respondents (Rahman et al., 2021). To determine changes in drivers' alertness scores at railroad crossings, compare drivers without using the DAD application and with the DAD application when crossing railroad crossings. EEG will continuously monitor the driver's focus value while crossing a level railroad crossing. EEG works with electrodes to record brain activity, which is reflected in the electrical voltage profile that appears. The EEG data collected in real time can be used to predict a person's concentration level with good accuracy (Kaushik et al., 2022).

EEG values are mapped according to the parts of the brain, namely the front, right, left, middle and back. The EEG wave frequency classification consists of alpha, beta, theta, and delta. Delta waves are in the frequency range between 0–4 Hz, Theta 4–8 Hz, Alpha 8–13 Hz, and Beta above 13 Hz. Different brain waves have different signal intensities at certain locations on the scalp and usually arise from different thought activities. The graph in **Figure 4** shows a comparison of recorded driver concentration values before and immediately crossing a level railroad crossing using a DAD map and without a map. Based on field data collection with 10 driver respondents, it was found that the average concentration when not using the DAD application was 48.97 and after using DAD it was 59.58 or an increase of 21.66%. The graph further shows that the DAD map can maintain driver concentration better. In detail, it can be said that there is a gradual increase in the concentration value of drivers towards the railway crossing. For the green zone (distance > 500 m) the concentration value is 52.72, while the yellow zone (500 to 100 m) has a concentration value = 58.60, and for the red zone (distance < 100 m) the average concentration is = 66.39.

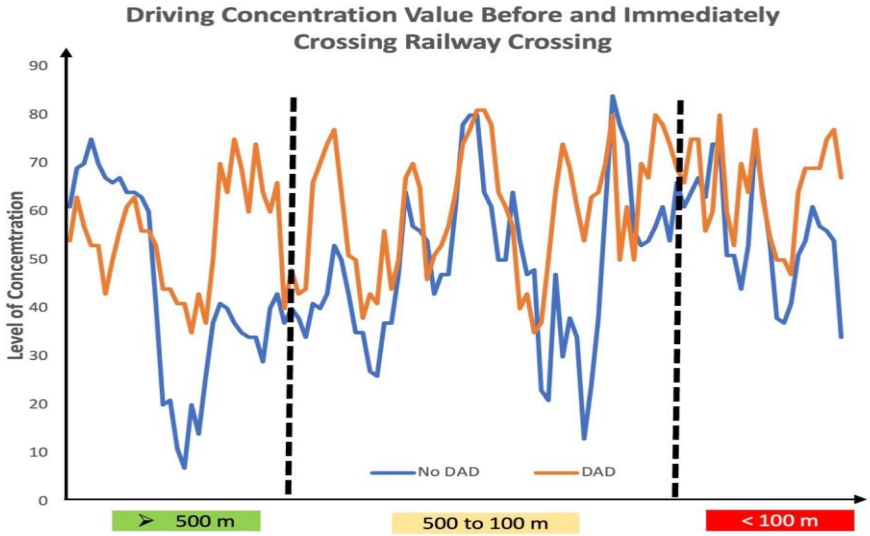


Figure 4. EEG recording results to assess driver concentration with and without DAD map.

The advantage of the Double Awareness Driving (DAD) map for the safety of drivers crossing railway crossings is that this application is mobile phone-based, which makes it easy to download and install. This application also allows it to be installed on various devices, including being integrated into the vehicle's visual display. DAD is the first map that works with other applications such as Google Maps or can be integrated with Google Maps and is able to provide "guidance" to drivers in real time before crossing railway level crossings. This application can be developed in the future not only for drivers, but will also integrate with driver information systems and warning alarms at crossings without gate/attendant barriers. While the weakness of the current DAD application is that it is still limited to railway crossings, in the future it could be equipped with road maps that provide information and early warnings about sources of danger on other highways. The application still uses the internet network to continuously update the road map that will cross the railway crossing. In the future, a database needs to be built so that it can be used on roads where there is no internet connection.

5. Conclusion

Driving accidents at railroad crossings are still very high, resulting in the loss of lives and material losses. The double awareness information system was built to increase focus and caution for drivers. The information system that was built provides information on the number of railroad tracks that will be traversed, both with gatekeepers and without gatekeepers or officers. In addition, the double awareness roadmap also provides dynamic guidance on the distance to the nearest railroad crossing in the form of 3 zone stages, namely the green zone for distances >500 m, the yellow zone for 500 m to 100 m, and the red zone for < 100 m. In addition, during the red zone, drivers will also receive updates on the position of the train, so they will continue to focus on preparing to stop when a train passes. The application that has been made has been tested for its ease of use through a visual display test in the form of a usability test. The usability test carried out resulted in a learnability value of 86.70, efficiency of 0.29 goals/s, errors of 0%, and a SUS score of 97.50 or category A (ready to use). The results of the EEG recording show that the DAD map can increase the driver's concentration by up to 21.66%. The closer driver get to a level railroad crossing, the higher the driver's level of alertness.

Author contributions: Conceptualization, SS; methodology, SS and EW; software, AAF, MAF, ARF, WHS and FM; validation, SS, BR and EW; formal analysis, SS and ARF; investigation, SS and AAF; resources, SS; data curation, ARF; writing—original draft preparation, SS and ARF; writing—review and editing, WHS and FM; visualization, FM; supervision, BR; project administration, ARF; funding acquisition, SS. All authors have read and agreed to the published version of the manuscript.

Acknowledgments: Our acknowledgment goes to the Ministry of National Education of the Republic of Indonesia for supporting this study. The researchers would also like to express their gratitude to the Brawijaya University, Malang, Indonesia, for their extraordinary encouragement. The study was performed with the financial support by Lembaga Penelitian & Pengabdian Masyarakat (LPPM) Universitas Brawijaya through DRPM grant 2023 program with grant no. 1145.5/UN10.C10/TU/2023.

Conflict of interest: The authors declare no conflict of interest.

References

Anderson, C. (2023). Fatal Florida train crash highlights dangers of private, unguarded crossings that exist across US | AP News. Available online: https://apnews.com/article/florida-train-suv-crash-family-killed-a7f40bba6b4508f4c59a44b9d0c77a8b (accessed on 25 September 2023).

Bao, S., Wu, L., Yu, B., & Sayer, J. R. (2020). An examination of teen drivers' car-following behavior under naturalistic driving conditions: With and without an advanced driving assistance system. Accident Analysis & Prevention, 147, 105762. https://doi.org/10.1016/j.aap.2020.105762

Caird, J. K., Edwards, C. J., Creaser, J. I., & Horrey, W. J. (2005). Older Driver Failures of Attention at Intersections: Using Change Blindness Methods to Assess Turn Decision Accuracy. Human Factors: The Journal of the Human Factors and Ergonomics Society, 47(2), 235–249. https://doi.org/10.1518/0018720054679542

Carofiglio, V., de Carolis, B., & D'Errico, F. (2019). A BCI-based Assessment of a player's state of mind for game adaptation. CEUR Workshop Proceedings.

Dezhkam, B., & Eslami, S. M. (2017). A review of methods for highway-railway crossings safety management process. International Electronic Journal of Mathematics Education, 12(3), 561–568. https://doi.org/10.29333/iejme/632

Endsley, M. R. (2017). Toward a Theory of Situation Awareness in Dynamic Systems. Situational Awareness, 9–42. https://doi.org/10.4324/9781315087924-3

Evans, A. W. (2011). Fatal train accidents on Europe's railways: 1980–2009. Accident Analysis & Prevention, 43(1), 391–401. https://doi.org/10.1016/j.aap.2010.09.009

Ghasemzadeh, A., & Ahmed, M. M. (2019). Quantifying regional heterogeneity effect on drivers' speeding behavior using SHRP2 naturalistic driving data: A multilevel modeling approach. Transportation Research Part C: Emerging Technologies, 106, 29–40. https://doi.org/10.1016/j.trc.2019.06.017

Guo, Z., Pan, Y., Zhao, G., Cao, S., & Zhang, J. (2018). Detection of Driver Vigilance Level Using EEG Signals and Driving Contexts. IEEE Transactions on Reliability, 67(1), 370–380. https://doi.org/10.1109/tr.2017.2778754

Hofbauer, M., Kuhn, C. B., Puttner, L., Petrovic, G., & Steinbach, E. (2020). Measuring Driver Situation Awareness Using Region-of-Interest Prediction and Eye Tracking. 2020 IEEE International Symposium on Multimedia (ISM). https://doi.org/10.1109/ism.2020.00022

Hogan, D., Crawford, J., Smit, D., & Smith, P. (2017). Wayfinding in the built environment stage 2 & 3: Final report, Brisbane, Cooperative Research Centre for Construction Innovation.

Hong, W.-T., Clifton, G., & Nelson, J. D. (2023). Railway accident causation analysis: Current approaches, challenges and potential solutions. Accident Analysis & Prevention, 186, 107049. https://doi.org/10.1016/j.aap.2023.107049

Hussain, A., & Mkpojiogu, E. O. C. (2016). Usability evaluation techniques in mobile commerce applications: A systematic review. AIP Conference Proceedings. https://doi.org/10.1063/1.4960889

Johnson, P. M. (2015). An investigation of railroad-highway grade crossing consolidation rating in Iowa. https://doi.org/10.31274/etd-180810-3941

Kasalica, S., Obradović, M., Blagojević, A., Jeremić, D., & Vuković, M. (2020). Models for ranking railway crossings for safety improvement. Operational Research in Engineering Sciences: Theory and Applications, 3(3), 85. https://doi.org/10.31181/oresta20303085k

Kaushik, P., Moye, A., Vugt, M. van, & Roy, P. P. (2022). Decoding the cognitive states of attention and distraction in a real-life setting using EEG. Scientific Reports, 12(1). https://doi.org/10.1038/s41598-022-24417-w

Li, C., Tang, T., Chatzimichailidou, M. M., Jun, G. T., & Waterson, P. (2019). A hybrid human and organisational analysis method for railway accidents based on STAMP-HFACS and human information processing. Applied Ergonomics, 79, 122–142. https://doi.org/10.1016/j.apergo.2018.12.011

Li, Q., Ng, K. K. H., Yu, S. C. M., Yiu, C. Y., & Lyu, M. (2023). Recognising situation awareness associated with different workloads using EEG and eye-tracking features in air traffic control tasks. Knowledge-Based Systems, 260, 110179. https://doi.org/10.1016/j.knosys.2022.110179

Mironer, M., Coltman, M., McCown, R. (2000). Assessment of Risks for High-Speed Rail Grade Crossings on the Empire Corridor. US DOT/FRA.

Nielsen, J. (1993). Usability testing. Usability Engineering, 165–206. https://doi.org/10.1016/b978-0-08-052029-2.50009-7

Oron-Gilad, T., & Borowsky, A. (2015). Hazard Awareness in Driving: Measurement and Training. The Cambridge Handbook of Applied Perception Research, 592–612. https://doi.org/10.1017/cbo9780511973017.036

Pamuła, T., & Pamuła, W. (2021). Detection of Safe Passage for Trains at Rail Level Crossings Using Deep Learning. Sensors, 21(18), 6281. https://doi.org/10.3390/s21186281

Park, P., Parisien, J., Sahaji, R., Cozier, C. (2021). Development of geographic information system to identify potential high collision locations in Saskatoon. Saskatchewan Government Insurance, Interim Report.

Rahman, Md. M., Sarkar, A. K., Hossain, Md. A., Hossain, Md. S., Islam, Md. R., Hossain, Md. B., Quinn, J. M. W., & Moni, M. A. (2021). Recognition of human emotions using EEG signals: A review. Computers in Biology and Medicine, 136, 104696. https://doi.org/10.1016/j.compbiomed.2021.104696

Rangra, S., Sallak, M., Schön, W., & Vanderhaegen, F. (2015). Human Reliability Assessment under Uncertainty—Towards a Formal Method. Procedia Manufacturing, 3, 3230–3237. https://doi.org/10.1016/j.promfg.2015.07.874

Read, G. J. M., Cox, J. A., Hulme, A., Naweed, A., & Salmon, P. M. (2021). What factors influence risk at rail level crossings? A systematic review and synthesis of findings using systems thinking. Safety Science, 138, 105207. https://doi.org/10.1016/j.ssci.2021.105207

Saccomanno, F.F., Fu, L., Park, P. (2017). Decision support tool for prioritizing safety improvement programs at high-risk grade crossings. Department of Civil and Environmental Engineering university of Waterloo.

Sagberg, F., Selpi, Bianchi Piccinini, G. F., & Engström, J. (2015). A Review of Research on Driving Styles and Road Safety. Human Factors: The Journal of the Human Factors and Ergonomics Society, 57(7), 1248–1275. https://doi.org/10.1177/0018720815591313

Schlatter, T., & Levinson, D. A. (2013). Visual usability principles and practices for designing Digital Applications. Morgan Kaufmann Publishers is an imprint of Elsevier.

SUS: A “Quick and Dirty” Usability Scale. (1996). Usability Evaluation In Industry, 207–212. https://doi.org/10.1201/9781498710411-35

Tuwanakotta, J. L., & Tanaamah, A. R. (2022). Evaluation of Usability Quality Between InDriver and Maxim Applications Using Usability Scale (SUS) and Usability Testing Methods. SISTEMASI, 11(3), 630. https://doi.org/10.32520/stmsi.v11i3.2001

Widyanti, A., & Qurratu Ainizzamani, S. A. (2017). Usability evaluation of online transportation’ user interface. 2017 International Conference on Information Technology Systems and Innovation (ICITSI). https://doi.org/10.1109/icitsi.2017.8331762

Wijayanto, T., Marcillia, S. R., Lufityanto, G., Wisnugraha, B. B., Alma, T. G., & Abdianto, R. U. (2021). The effect of situation awareness on driving performance in young sleep-deprived drivers. IATSS Research, 45(2), 218–225. https://doi.org/10.1016/j.iatssr.2020.10.002

Zhang, B., de Winter, J., Varotto, S., Happee, R., & Martens, M. (2019). Determinants of take-over time from automated driving: A meta-analysis of 129 studies. Transportation Research Part F: Traffic Psychology and Behaviour, 64, 285–307. https://doi.org/10.1016/j.trf.2019.04.020