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Design of an Information System for Safety-Briefings along Planned Routes

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Completed Research

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Abstract

Despite continuous improvements in road and vehicle safety, traffic accidents are still a threat to humans. Road safety even became a target of a sustainable development goal, presented by the United Nations (UN). Traffic-accidents often occur in certain areas. Thus, a briefing before driving a route could support drivers in knowing the dangerous spots and driving more careful and attentive at the dangerous areas. Following a design science research approach, we develop a theory how briefings for traffic related dangers should be designed and a web-application as an instance of the theory.

Keywords

Driver briefing, Road Safety, Sustainable Development Goals

Introduction

The United Nations released a 2030 agenda for sustainable development. The core of the agenda published in 2015 are 17 sustainable development goals (SDGs) with 169 associated targets that tackle the most impactful challenges of the world (United Nations (UN) 2015). The SDGs reach from ending poverty (SDG1) to strengthening the means of implementation and revitalizing the global partnership for sustainable development (SDG17). Information systems (IS) can play a significant role in contributing to the SDGs (Leong et al. 2020). Improving road safety is addressed in SDG3 (Ensure healthy lives and promote well-being for all at all ages) target six (United Nations (UN) 2015).

There are many approaches improving traffic safety with IS (Hasnain Anwar et al. 2021; Tan et al. 2021). These mainly focus on providing information while drivers are driving (Hasnain Anwar et al. 2021). Nevertheless, too much information can lead to technostress that could lead to a worse performance of the driver (Kim and Park 2018; Tarafdar et al. 2015). Thus, in this paper, we transfer an approach from aviation (Cahill et al. 2013) to road traffic: a pre-trip briefing that points out safety-relevant road sections to drivers. Hence, the aim of this paper is to provide individual actors in road traffic with an instrument to increase the safety of a travel route. The focus is identifying danger spots, their associated weather conditions, and the current weather in order to provide the driver with an assessment of a planned route. To address this research gap, this article aims to answer the following research question.

(RQ)*: How should a pre-trip route briefing information system for traffic safety be designed?*

To answer this question, we follow a Design Science Research (DSR) approach (Hevner 2007; Hevner et al. 2004) to develop automatically generated driver briefings, which we refer to as the Danger Spot Briefing (DSB). The DSB enables users to gather information about the most dangerous spots on their next route. For the identification of danger spots, we analyzed a German database for accidents (Statistische Ämter des Bundes und der Länder 2022) and literature with focus on accident causes. An expert-evaluation of the final DSB showed promising results for safer road trips especially in unknown areas for the respective driver.

Background

Weather related accident causes

Traffic accidents in general are described as indicators of malfunctions in the road traffic system (Huvarinen et al. 2017). To detect and prevent such malfunctions in the growing road traffic system, different factors are being researched to reduce possible risks in road traffic. Acquiring better knowledge of reasons and conditions of road crashes is a key element of a proactive safety management. Therefore, it is crucial to understand the various factors that can lead to an accident (Theofilatos and Yannis 2014). The influence of weather factors on the traffic risk has been topic of numerous research (Bergel-Hayat et al. 2013; Heqimi et al. 2018; Qiu and Nixon 2008). While the most common conclusion is that adverse weather is a relevant factor for increasing crash rates, there are also findings, that weather factors can lead to decreasing traffic rates which influence crash rate numbers (Maze et al. 2006). Traffic safety as well as traffic demand and traffic flow depend on weather factors (Maze et al. 2006). Adverse weather can reduce the traffic demand, leading to a reduced number of vehicles in the road system and therefore a reduced total number of road accidents (Maze et al. 2006). However, a reduced number of road accidents does not indicate a lower crash rate. In general, the crash rates in adverse weather are seen to be increasing (Maze et al. 2006). While weather matters, the general pre-accident situation can be crucial for the occurrence of a road accident (Malin et al. 2019). It is shown that the accident risk is higher on single-lane roads and that there is a higher risk for single-vehicle accidents (Malin et al. 2019).

In the pre-accident situation, the occurrence of precipitation can be relevant. Longer intervals with no or little rainfall can lead to a higher crash risk than at rainfall conditions within a longer period of persistent rainfall. There are two main reasons for these findings, one being that oil, dirt and grime are washed away by rainfall from the road pavement after a longer period of no rainfall at all. These result in a more slippery road surface than there would be after a longer period of rainfall. At the beginning of a rainfall period, road traffic participants are not as used to the weather conditions as they are after a longer period of consistent rainfall. Therefore, the crash-risk at rainfall increases at the start of a rainfall period (Sangkharat et al. 2021) but decreases after a longer time of rainfall (Lobo et al. 2019).

Regarding precipitation, it should be emphasized that snow and ice can pose the highest risk. This is due to the more increased reduction in road grip (Malin et al. 2019). While most research of weather effects on road accident risk consider precipitation, high winds are also a relevant environmental factor that must be regarded as a crash risk (Qiu and Nixon 2008). Overall, the current state of research shows, that weather conditions have an important and significant impact on the road safety and that the understanding of these effects is a key element to minimize crashes in adverse weather conditions (Heqimi et al. 2018).

Briefings in the mobility context

A briefing is a meeting in which people are given instructions or information (Turnbull 2010, p.132). A briefing includes a significant amount of information that can be relevant for different participants and the success of a process (Bouchlaghem et al. 2000). Briefings are most commonly used in high hazard environments to reduce risks. The most popular environment is the aviation industry where briefings are a common tool to increase safety (Molesworth et al. 2018) The pre-flight briefing involves the review of all necessary information that is important for the flight, including a flight-route, the weather and further important information that can have any effect on the flight (Cahill et al. 2013). These briefings should be standardized, and the aim is that every attendant is familiar with each other, the flight plan, and the route factors. The quality of these briefings is decisive for the performance of a crew throughout a flight (ŞTEFAN 2017). Briefings can be an option to influence the overall mood of participants as an efficient and informative briefing can lead to a good mood. As mood is a state that can link to performance, a good mood can increase performance, while a bad mood can cause an overall bad performance (Molesworth et al. 2018). One specific form of briefing is a self-briefing which is obtained by using different resources of information, which is gathered and prepared in order to provide each user with the most relevant information. An effective self-briefing can be obtained by pilots using special information gathering applications and increase their overall safety. For those applications to be effective however, it is important that they are easy to use, well-designed and output the most efficient data possible, and that they are easy to understand and rich in information (Domingo and Blickensderfer 2021). In conclusion, a good and effective briefing should focus on the key information, convey the objectives, create the necessary understanding background, and only provide the necessary information (Back and Beuttler Stefan 2006).

Methodology

This work aims to answer the research question by using accident data and implementing a planning and briefing system, considering findings from the literature. To achieve this goal, the combined Design-Science-Research (DSR) framework (Hevner 2007; Hevner et al. 2004) is used. DSR has achieved a general acceptance in the Information Systems (IS) field with its popularity increasing (Gregor and Hevner 2013). Considering the needs of the environment and existing knowledge, artifacts are iteratively developed, evaluated, and continuously improved (Hevner 2007). DSR is not only focused on problem solving, but also capable of producing knowledge, which in turn can be used as a reference for the further development of theories. This can reduce the existing gap between theory and practice. The DSR framework essentially consists of three cycles that are run through iteratively. The relevance cycle, in which the project environment is examined in more detail and the requirements for the artifact to be developed are defined. The environment is the environment in which the problem is observed, and the artifact will operate. The Rigor Cycle to check which knowledge is needed in advance and which tools are available. And finally, the design cycle, which is an equally iterative process between the development and the evaluation of the artifact. The complete run of all cycles is called iteration. Our research approach is shown in Table 1. In the following sub-sections, we describe the research process in more depth.

	Iteration 1		
	Relevance Cycle	Rigor Cycle	Design Cycle
Input	• Crash Data • Map providers	• Literature review on road crashes • Literature review on weather effects • Literature review on information systems • Expert interview • System requirements	• Requirements • Crash-Data • Map-framework
Method	• Web research	• Literature review • Evaluation	• Artifact conception
Steps	• Search providers • Test Map-providers	• Analyse Literature • Conduct interview • Identify meta-requirements	• Design artifact
Results	• Problem definition • Provider overview • System requirements	• Meta-requirements	• Artifact design
	Iteration 2		
	Relevance Cycle	Rigor Cycle	Design Cycle
Input	• Expert-Interviews (Briefing and Driving Safety) • Artifact design	• Updated system requirements	• Updated requirements • Results of literature review
Method	• Evaluation	• Literature review	• Artifact prototyping
Steps	• Conduct interviews	• Analyse Literature	• Develop artifact • Evaluate
Results	• Update system requirements	• Updated meta-requirements	• Artifact

	Iteration 3		
	Relevance Cycle	Rigor Cycle	
Input	• Artifact • Expert discussion	• Artifact Design	
Method	• Evaluation	• Documentation	
Steps	• Conduct Interview	• Analyse design • Complete documentation	
Results	• Evaluated Artifact	• Documentation • Design theory	

Table 1 Overview of performed iterations

Iteration 1

The objective of the first iteration is to develop a concept for the artifact. To realize this, the environment of crash data was initialized within the relevance cycle. Therefore, research towards available and extensive crash data was conducted. This served the general assessment of the possibilities of using crash data. Furthermore, web-map providers were looked at, to achieve a selection of frameworks or libraries that could potentially be used. Finally, system requirements based on crash data and web-map providers were defined. Within the rigor cycle, the system requirements and crash data were used as a basis for a targeted literature research. A structured approach was applied (vom Brocke et al. 2009; Webster and Watson 2002) to achieve efficient and conducive results. For the literature review, a wide range of search terms were used to achieve a wide selection of initial results. This wide selection meant a higher effort for analyzing the found literature, but also gave detailed and suitable results. Based on these results, the meta-requirements were derived. In addition to a literature review, interviews were conducted with experts from aviation and safety-driving training. These interviews confirmed that a briefing system for road users should be considered. Briefings are a well-used feature in the aviation industry and have achieved the must-use status in terms of safety and planning. The experts further stated that a route planning for drivers could benefit from a risk briefing prior to a journey, especially if the drivers don't know the route and road with its known crash spots. Finally, the weather was seen as a key factor, what corresponds with the results of the literature review. The results of these interviews were used to expand and adjust the meta-requirements. The results from both cycles were then combined in the design cycle. Table 1 shows the resulting knowledge which was transferred into a first design of the artifact.

Iteration 2

The aim for the second iteration was the further implementation of the artifact. To evaluate the existing artifact design at the present point, further expert interviews were conducted. The interviews showed that weather factors should receive even more attention both in research and in the design of the artifact. As a result, the meta-requirements were specified and a detailed review of weather factors for road users added to the following rigor cycle for one more literature review. The described procedure of the literature review from iteration 1 was applied here. The expanded meta-requirements and the results of the literature-review were transferred to the design cycle and used for the development of an artifact prototype. To fulfil the defined requirements, JavaScript libraries, the openrouteservice-API (Openrouteservice 2022) and the openweathermap-API (OpenWeatherMap 2022) were used.

Iteration 3

In the third iteration, the artifact was further evaluated within the relevance cycle. For this purpose, the requirements were aligned with the artifact. To externally evaluate the artifact design, the artifact was discussed with the previously interviewed experts and as a result, it could be determined that all requirements were met, and no further additions were needed. In the following rigor cycle the achieved knowledge from the previous iterations was reviewed and documented. The discussion with the experts was used to for a final assessment of the artifact's design. The design was also considered to be complete and met the requirements. Finally, documentation of the artifact was prepared.

Results

Danger spot briefing

The existing crash prevention in road systems is based on crash prediction methods and the usage of road warning signs at places like sharp corners or bad road surface. These signs are mostly static and provide a general warning to road users. Such warning signs may not always be fully recognized or taken serious by road users, as they could believe that the risks shown by them will not affect them (Charlton 2006). Furthermore, an existing web-application, the “Unfallatlas” from the Federal Statistical Office of Germany provides a map, based on crash data of all German road accidents leading to injuries or deaths. This map contains filter options, for example, regarding the type of vehicle involved. This map provides a good general impression of road accidents in Germany, but it misses an option to filter crashes by weather and daytime factors. As already described, these factors can be relevant for the occurrence of a road crash. This problem motivates the challenge of how to filter this accident data according to weather conditions and time of day and provide users with an effective warning of danger spots. This warning should be both effective and brief, sufficiently comprehensive, and issued in the context of a user's planned itinerary and the prevailing weather. During the DSR cycles, requirements could be derived from the environment, literature, and expert interviews. These are divided into requirements relating to data collection (RDC), data usage (RDU) and the information and briefing system (RIB). An overview of the requirements is compiled in Table 2 and explained below.

R_{DC}	Data collection	
	R_{DC1}	Data quality
	R_{DC2}	Accessibility
	R_{DC3}	Performance
R_{DU}	Data usage	
	R_{DU1}	Map display
	R_{DU2}	Map filter options
	R_{DU3}	Route data
	R_{DU4}	Weather data
	R_{DU5}	Match route and weather data
	R_{DU6}	Briefing data summary
R_{IB}	Information and briefing system	
	R_{IB1}	Web application
	R_{IB2}	User interface
	R_{IB3}	Briefing details

Table 2 Requirements

The data collection (RDC) is the essential basis, both for a good representation of accidents that have happened and for qualitative route planning. For this purpose, three criteria have been defined. The data quality (RDC1) is crucial for the correct display of accident points and the accurate calculation of the route. Furthermore, it is important for a correct weather forecast of the route. The accessibility (RDC2) is key to obtain this data. The data for route calculation and actual weather are likely to be received from API calls. Therefore, it is important that the sources for these are accessible without great amounts of downtime or access restrictions. Since the artifact will handle large amounts of data, not only the crash data but also route coordinates and weather data, it is important to pay attention to the performance (RDC3) of both the data retrieval and usage. This includes paying attention to the overall performance of the artifact.

The collected data should be used and presented according to different aspects and criteria. To achieve this, six criteria were set for the requirements (RDU). The crash data and a requested route should be displayed on a map (RDU1) to obtain a first impression of the planned route and potential overall risks. This map should offer an option to select desired data elements (RDU2) such as weather factors, daytime, and vehicle type. The planned route (RDU3) should be clearly presented to the users, so that they get an overview of distance and travel time. To prepare the users for upcoming weather, the weather (RDU4) at start and destination should be presented. The route data and weather data should be combined (RDU5) to check the upcoming weather along the route. If adverse weather is detected, this should be displayed. The combination of the route display, the display of the accident locations and the expected weather is intended to give users a first overall impression. Finally, all the obtained data should be summarized (RDU6) and displayed as a briefing with the most important facts.

For the implementation of the requirements of the data usage (RDU), an information and briefing system (RIB) should be designed. To enable a broad field of use, the system should be designed as web application (RIB1). A user-friendly and interactive design (RIB1) is to be implemented for this web application (RIB1). It should be clearly structured and easy to understand. The most important data resulting from the use of the application should be presented in a clear and comprehensible route briefing. The interface should not appear overloaded and should only contain the most important facts to not overwhelm the user.

Next, we developed a web application using HTML, CSS and JavaScript to implement the graphical user interface (GUI). With jQuery (jQuery 2022) and Bootstrap (Bootstrap 2022), libraries and frameworks were used to make the design and programming efficient and effective. When the web application is called up, the user interface is presented to the users while the accident data is loaded from a .csv file from the server in the background. This data was left in a .csv file for simplicity for this project. The loading of this data takes place asynchronously, so that the users do not have any noticeable waiting times. When users perform a route query, two asynchronous API requests for weather and route information are performed. The result of these queries is processed by the application and presented to the users via the GUI. Furthermore, this data is compiled into a briefing and presented. This structure is illustrated below in Figure 1.

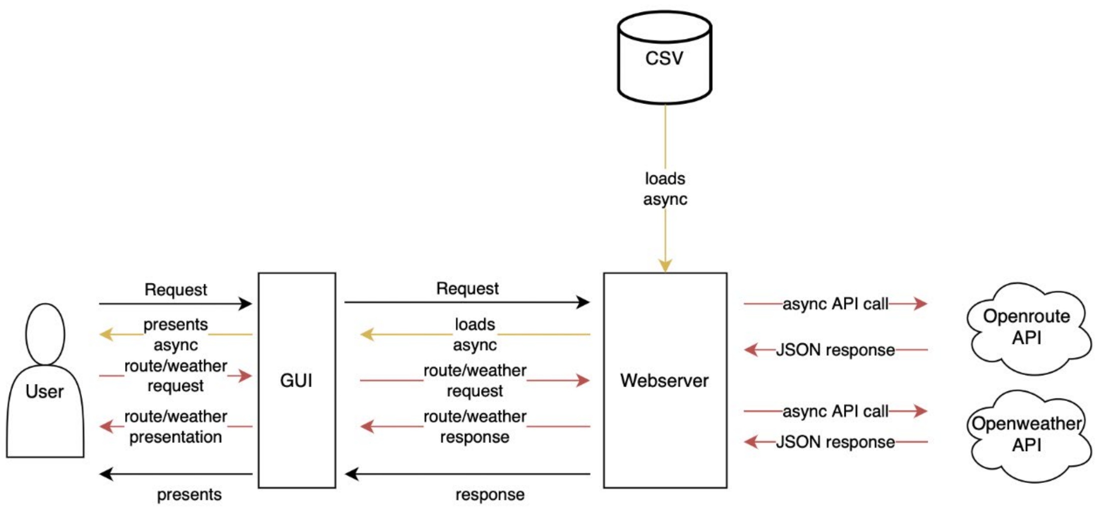

Figure 1 Structure of the artifact

The data required for route calculation and the weather data are requested via API interfaces. For the route query, the service of *openrouteservice* (Openrouteservice 2022) was used. The weather data were collected via the *OpenWeatherMap* (OpenWeatherMap 2022) service. If a route query is made, requests are sent asynchronously to both APIs. These process the requests and send their results back to the web server as JSON. The artifact now accesses this JSON data and extracts the information needed to display the route, the information about the route and the weather data at the starting point, destination and during the route. Finally, the most important data is compiled into a briefing. An example for dangerous spots along a route is depicted in Figure 2. Figure 3 shows the route's general risk assessment next to the weather information of start, middle and destination of the given route.

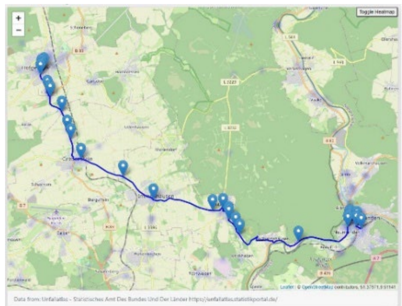

Figure 2 Dangerous spots along a route

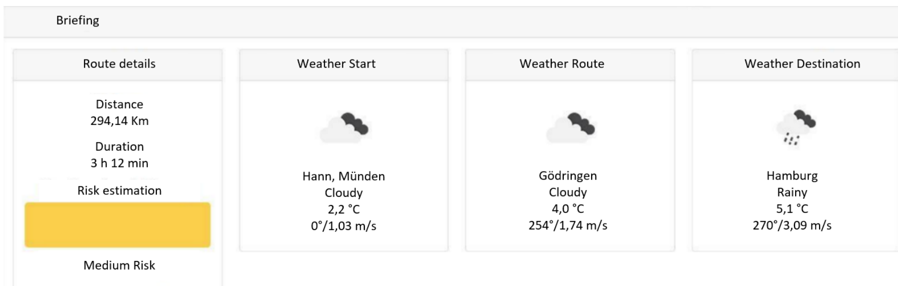

Figure 3 Weather information and general risk assessment of the route

Design Theory

To add to both theory and practice we developed a design theory for driver briefing systems based on (Gregor and Jones 2007). The resulting design is given in Table 3. The design theory enables further work on briefing systems for road safety by providing the six core components of a design theory (Gregor and Jones 2007).

Components	Description
Purpose and scope	Brief road users about dangerous spots on their route
Constructs	Route planning, Briefing and Accidents
Principles Form and Data	Data collection (R_{DC1}, R_{DC2}, R_{DC3}) Data Usage (R_{DU1}, R_{DU2}, R_{DU3}, R_{DU4}, R_{DU5}, R_{DU6}) Information and briefing system (R_{IB1}, R_{IB2}, R_{IB3})
Artifact mutability	Adaptation for use in navigation systems
Testable Propositions	Using a system that derives danger spots by analysing historic accidents, current weather data and the planned route as well as informs the user about the results will lead to less traffic accidents.
Justificatory knowledge	Traffic accident literature and briefing literature.

Table 3 Design Theory of Driver Briefing Systems (following Gregor and Jones 2007)

Discussion

The field of traffic risks with their causes and the prevention of these risks offers a large and interesting field of research. This paper offers a contribution to research with the results from the DSR process and the resulting design theory. We transferred knowledge about safety-briefings from aviation to driver briefing and present these as a new way to contribute towards SDG 3 target six with IS. The developed artifact offers an approach to combine road safety factors with briefings. Furthermore, the research area of driver assistance systems and the associated integration of further functions is a possible avenue for future research regarding the artifact. Here, the combination with connected driving is particularly suitable, perhaps in order to automatically load new accident points into the databases of the vehicles in the future and thus inform the drivers about risks in the best possible way and as up-to-date as possible.

The presented development of the briefing system contributes to DSR (Gregor and Hevner 2013) by providing an application that supports safer traffic with a briefing. Thus, both application domain maturity as well as solution maturity can be seen as low. Subsequently, our developed briefing system and its instantiation as a web application can be categorized as an improvement, as it improves the solution space by adding a new approach to the knowledge base. To our knowledge there is no prior DSR related work on briefing systems. Thus, we contribute to the traffic safety domain by presenting briefings to inform users before they take difficult or dangerous tasks in traffic. Our application supports drivers informing themselves about dangerous spots on routes they plan to take. We contribute by using the widely accepted DSR Methodology to develop an original design theory for driver briefing systems following Gregor and Jones (2007) by using briefing knowledge from aviation and hazard knowledge from road safety research (Leidner 2020).

In addition to our theoretical contributions, this study presents implications for practitioners. Firstly, we present briefings as a new and easy way to enhance traffic safety. By proposing a new solution for the practical problem of traffic accidents we might inspire practitioners to include safety-briefings for routes. For example, navigation providers should consider integrating a briefing into their systems.

Nevertheless, this study has limitations. First, the evaluation of the artifact was conducted with experts from aviation and professional driving instructors and just very few users. Even though evaluation showed promising results it remains to be seen how drivers will use the briefing system. However, a broad mass of tests and feedback on the artifact is lacking. This means that a representative assessment of the artifact's functionality, range of functions and usefulness is not fully possible. Another critical factor for the artifact is to establish general user acceptance. We showed that briefings run the risk of overwhelming their users. The evaluations carried out also provided an initial assessment of the wealth of information and the overview of the artifact. However, this aspect requires a comprehensive and representative survey. The artifact's functionality depends on the underlying data records of accidents that have occurred. The data set currently used is the most recent from the Federal Statistical Office of Germany and includes traffic accidents from 2020. In the future, various factors and the accident data itself may change. For example, accident blackspots may have already been mitigated or new danger points may have arisen due to construction work and new routes, which cannot be detected by the artifact at the present time. These limitations could be eliminated or reduced by shorter intervals between accident data updates. Second the knowledge base on briefings for drivers is very sparse yet we are confident a transfer from aviation is a valid approach. Lastly, the real effect of the briefing system can hardly be measured since traffic accidents happen very rarely.

Conclusion

The aim of this paper was to develop a web application that shows users danger spots along a planned route and provides them with a briefing on their route and the danger spots. The research question *How should a pre-trip route briefing information system for traffic safety be designed?* was answered with the knowledge gained in extensive literature reviews and the requirements thus established. The results from the literature reviews provided first approaches to solutions from which a prototype was developed to fulfil the established requirements, which was also confirmed expert interviews. For the future, the use of accident data as a basis for hazard prediction in assistance and navigation systems offers considerable opportunities to further increase road safety. Through the efficient, timely and up-to-date warning of danger spots in such systems, road users would not have to inform themselves separately about each risk in advance and could still receive a safety gain.

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