ARTIFICIAL INTELLIGENCE MODEL FOR AN IMPROVED OCCUPATIONAL SAFETY IN RAILROAD MAINTENANCE

PhD. thesis – Summary

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1. Summary of the PhD Thesis

Transportation systems have been throughout time crucial for the advancement of our society. Passenger transportation was for instance crucial for migration, while goods transportation has always been quintessential for trading as one of the fundamental economic activities in every society, regardless of the age. A transport system can be defined as the set of elements consisting of the vehicle and the transport path, used in the movement of passengers or goods. Today there are conventional and nonconventional transport systems. Conventional transport systems are:

- Road transportation;
- Rail transportation;
- Water transportation;
- Air transportation;
- Pipeline transportation;
- Combined transportation.

Non-conventional transport systems include such technological advances as pneumatical systems, air cushion transportation or suspension railway systems. Rail transportation offers some crucial advantages, which individualize this type of transport under the conventional transportation systems in use. These advantages include the relatively high transportation speed, the high transportation comfort, as well as the balanced cost of transportation. Rail transportation also has a high acceptance degree in society, as it is ecologically harmless. In addition, there are few people in society who fear train travel (this fear is called siderodromophobia), unlike air travel [1].

Road transportation is the only type of transportation which can take place individually, as all the other transportation types, including rail transport, are mass transport systems. This is caused mainly by the price of vehicles – while cars have become an affordable means of transportation throughout history, this cannot be postulated about train cars or airplanes.

Another important observation is the difference between road and rail transportation on one side and air and water transportation on the other side regarding the necessary infrastructure. Road and rail transportation require special amenities (the road and the railway), which must be built, before transportation can take place and maintained afterwards, too. This is not the case for air and naval transportation, as these types of transport take place while using natural resources, without the need to build the infrastructure for the actual transport. Of course, for the start and the end of the transportation process amenities like a port or an airport are still needed.

Most countries in the world have railway infrastructure, albeit to a higher or lesser extent. There are few countries in the world and even fewer in Europe (such as Cyprus, Andorra, Malta or Iceland [2]), which do not possess railway infrastructure at all. The reasons are mostly financial or the countries are too small to be able to maintain such infrastructure.

The United States have the largest rail infrastructure in the world – about 300.000 km.

Other large countries with large rail infrastructure include China (approximately 124.000 km), Russia (approximately 87.000 km) and Canada (approximately 78.000 km). The first European country in the ranking of the length of the railway infrastructure is Germany with approximately 43.000 km, followed by France with about 30.000 km and Ukraine with nearly 22.000 km.

Recent changes in fuel pricing, as well as heightened awareness of environmental issues, have resulted in a greater emphasis on rail freight and passenger transportation in Europe. However, unlike road transportation, railways transportation does not provide any immediate diversion or bypass options, making system availability through timely and focused maintenance even more critical.

The railroad maintenance is a complex topic, crucial for the availability of one of the most eco-friendly means of transport. The maintenance of the railway infrastructure comprises a sequence of actions – challenging through more than one aspect. An unmaintained railway infrastructure becomes impassable, thus rendering railway transportation also unusable.

Railway maintenance is also a costly affair, as both inspections and maintenance are highly specialized - they require both qualified personnel and expensive machines. For this reason, infrastructure companies must closely weigh if a track can be maintained in a profitable or at least cost-covering manner.

In Germany the infrastructure is owned and maintained by the German government through the state-owned company named Deutsche Bahn AG (abbreviated *DB AG*).

This holding comprises more than 1000 companies, each responsible for a different activity related to either railway infrastructure or rail transport operation. The most important companies among them are:

- DB InfraGO AG – rail track and railway station maintenance and rental;
- DB Energie GmbH – overhead contact line maintenance;
- DB Fernverkehr GmbH – long-distance rail transport operation;
- DB Regio AG – short-distance rail transport operation;
- DB Cargo AG – freight rail transport operation.

There are also other companies which address other markets (the best known is DB Schenker – freight transport operations on land, sea and by air) or cater to internal processes of the holding (like the DB Fuhrparkservice GmbH – the company which owns all cars in use by employees of the holding).

The approximately 43000 km rail tracks in Germany are owned and maintained by DB InfraGO AG. This company is organized in seven geographical regions (North, West, South, Southeast, East, Southwest and Center) comprised of 34 networks. Each of the networks administers roughly 1000 to 1300 km rail tracks and is usually based in one of Germany’s bigger cities – for instance the network Kassel owns and maintains the rail tracks in and around the German city of Kassel.

The infrastructure company DB InfraGO AG is a public limited company, whose shares are and always were fully owned by the German state. The yearly budget of the company is thus in part allocated by the state through a subsidy – this budget can however only be used for track renewal and construction.

The state subsidy is approximately 10 billion € per year and variates marginally every year. For instance, more than 12 billion € were invested in 2021 by the German state in track renewal and construction, for 2023 only 8,85€ are projected, rising again to 10,6 billion € in the year 2026 [5].

The maintenance of existing track lines, however, must be financed with the own funds of the company. These own funds are generated by renting time slots for the use of the railway infrastructure by rail transport companies. These companies are DB internal companies (like DB Fernverkehr, DB Regio or DB Cargo), as well as third-party companies. If a rail transport company must carry some goods from Hamburg in northern Germany to Basel in Switzerland it must license use rights for all the rail tracks which will be traveled on. The same rule applies if for instance some wagons with goods must be stationed for a definite period in a train station.

One of the biggest challenges in this matter is that track maintenance heavily relies on manual work, even when using specially designed machines. Considering that railway maintenance mostly takes place while still upholding rail traffic (at least in one of the neighboring tracks), it becomes apparent why work safety is one of the main concerns. Sadly, it is not always easy to choose the best course of action to guarantee the safety and well-being of the workers, as many factors and criteria must be taken into consideration. There is no sole solution which can always be applied – the appropriate, most secure solution is decided through an individual case analysis. This individual case analysis is relatively error-prone and relies on the human factor to take into consideration all relevant aspects – any judgement or analysis error could lead to an erroneous decision which in turn could have a catastrophic turnout.

This PhD thesis analyzes the current decision-making process regarding work safety during railway maintenance works such as railway inspections or railway repair works in Germany. Thus, the research results propose replacing the paper-bound, error-prone system using an IT-based decision support system to alleviate the heavy workload and high responsibility of the taken decisions in this domain of critical importance to the modern society.

The identified **knowledge gap** in this context revolves around the inadequacies and risks associated with the paper-bound decision-making process for work safety during railway maintenance activities in Germany. Occupational safety is an omnipresent topic when planning railway inspections or railway repair works in Germany. Unfortunately, the paper-bound process poses high risks of error and consummates important human resources.

The main argument for choosing this research topic is therefore the need to achieve **higher work safety** for the employees, through a digital solution which does not allow certain errors or false information, which could lead to erroneous decisions. As human lives are at stake, it is not acceptable to base important decisions in this matter on manually researched information, just as it is not acceptable to leave room for human error when processing this data.

This argument is becoming with every year that passes more and more important, as the demographic change is accentuating. The railway industry in Germany (represented specifically by the DB InfraGO AG – see [6]) has not been spared the problems of a shortage of skilled workers and age-related departures. To elaborate on the topic: skilled, experienced workers are leaving the company and no adequate replacement can be found. Therefore, digital solutions which **lower the workload** of the existing employees are urgently required.

Another valid reason is the impact on the environment. Printing a 6-page-form for each inspection or instance of repair works places a high burden on the environment, not to mention the costs it incurs for the company. **Reducing the environmental impact** is the third main argument in choosing this research topic: through digitalization of the current process and the therefore no longer necessary printing of the safety plans, tons of paper and ink are no longer needed.

The **main objective** of the scientific research developed during the PhD. program is ***to define a solution for the digitalization of the decision-making progress regarding work safety during railroad maintenance activities in Germany***. A variety of domains of knowledge are included in the research methodology. The research topic of this thesis lies at the confluence of crucial topics like the process optimization regarding safety planning, the human resource (HR) management, the workforce security and of course the efficient design of railway maintenance (Figure 1.1).

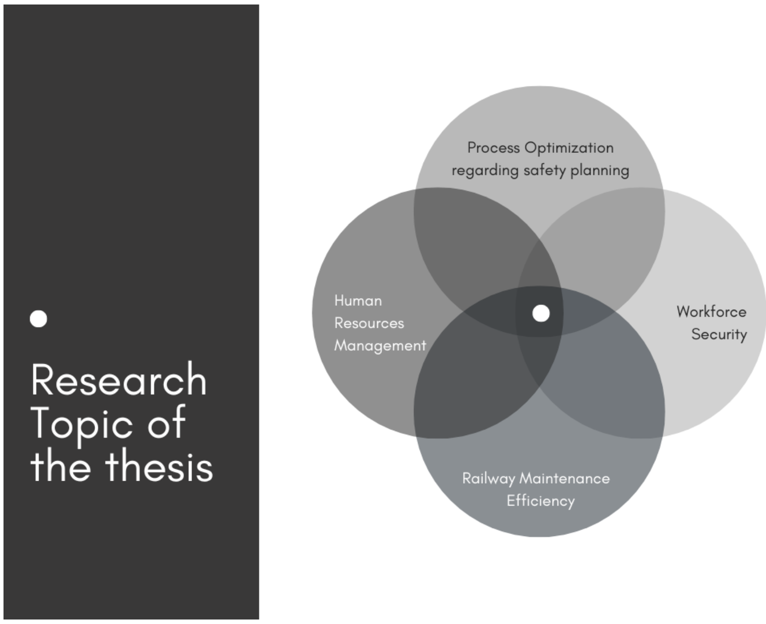

Figure **Error! No text of specified style in document.**.1 Research topic of the thesis (own representation)

The following specific objectives were proposed to achieve the main objective of the research presented in the PhD thesis:

O1) Analysis of use cases of digital decision-support systems:

(A1.1) Bibliographical study of decision-support systems (DSS);
(A1.2) Bibliographical study of occupational safety;
(A1.3) Analysis of use case of DSS in occupational safety;

O2) Identification of the main disadvantages of the current decision-making process regarding work safety during railroad maintenance works in Germany:

(A2.1) Analysis of current sources of error in the decision-making process;
(A2.2) Analysis of the time currently required for writing safety plans;
(A2.3) Analysis of paper consumption through printing the paper-bound safety plans;

O3) Identification of necessary databases for a digital decision-support system regarding work safety during railroad maintenance works in Germany:

(A3.1) Identification of required information in the decision-making process;
(A3.2) Definition of required information sources;
(A3.3) Establishing the necessary databases and their format;
(A3.4) Creating the databases for the digital DSS;

O4) Establishing logical connections between databases, as well as between databases and user input:

(A4.1) Definition of use cases of the databases;
(A4.2) Establishing logical connections between user input and the databases;
(A4.3) Establishing logical connections between databases;
(A4.4) Establishing database output;

O5) Implementing the decision support system in the form of a PC application:

(A5.1) Development of the software;
(A5.2) Design draft;
(A5.3) Testing the PC application;

O6) Case study with several different instances and analysis of the positive effects of the new system:

(A6.1) Establishing different modules / routines of the software;

(A6.2) Elaborating the safety plans for these modules / routines while using the current system;

(A6.3) Elaborating the safety plans for these modules / routines while using the new system;

(A6.4) Result comparison and result analysis;

O7) Dissemination of the results:

(A7.1) Publication of at least 2 ISI/ISI Proceedings articles;

(A7.2) Publication of at least 3 BDI-indexed articles;

(A7.3) Participation at 3 international conferences;

08) Writing the doctoral thesis;

09) Defending the doctoral thesis.

For the general theoretical part of the thesis, such as the following analysis of decision support systems, the author used bibliographical resources available through the "e-nformation" portal offered by the Politehnica University in Timisoara via Anelis organization. Another tool that was used was Semantic Scholar (available under https://www.semanticscholar.org/).

The research regarding the railway-specific theoretical part of the thesis was conducted with the help of an internal database of the German railway infrastructure company DB InfraGO AG. Such relevant sub-legal framework – the DB guidelines – is available for order through the company named DB Kommunikationstechnik GmbH but can also be freely accessed by employees of the German railway company. As the author of the present thesis is affiliated with DB InfraGO AG, the latter method was used.

For the programming and testing of the PC application, as well as the case study (see objectives O5 and O6) a high-performance laptop with several software licenses has been used. To ensure maximum compatibility, other computers with different technical specifications were used during the testing phase (A5.3). This was also done to be able to identify the minimum requirements for a computer to run the software FRIDA S in a satisfactory manner. For phase (A6.3) a system with medium specifications was used in determining the amount of time saved by elaborating the safety plans for the uses cases while using FRIDA S. The system was operated by an experienced, schooled user with theoretical and practical experience in the field of safety plan elaboration.

During the writing process of the doctoral thesis (O8), several modern tools such as ChatGPT [26] and Quillbot [27] were used with respect of the *General Decision no. 85/25.05.2023* of the Politehnica University of Timisoara Senate. Both tools were primarily used for composing better formulations in English, as parts of the text were originally written in German or Romanian (the author's native languages). Furthermore, ChatGPT version 4 was also used for research purposes and for generating options for improving the decision-support system.

The scientific research related to the PhD program is presented in 6 chapters and 21 subchapters.

The first chapter - "Introduction" - defines the objective of the thesis and offers the arguments (both subjective and objective) of the author for choosing this research topic.

The second chapter – "Managing work safety in railroad maintenance – state of the art" - formulates some general considerations on work safety with the support of bibliographical research. Subchapter 2.2 offers an overview of the railroad maintenance process in Germany, highlighting the different types of railway inspections and offering insights in the railway repair works. Subchapter 2.3 focuses on the possible courses of actions to ensure workforce security during railway inspections and railway repairs, presenting their advantages, disadvantages and respective exclusion criteria. Subchapter 2.4 summarizes the challenges and factors for work safety in railroad maintenance, thus creating a link to the following chapter.

Chapter 3, entitled ***"Theoretical Research for Designing a Concept Model for a Decision Support System Regarding the Work Safety in Railroad Maintenance"***, forms a comprehensive foundation for the development of a digital decision support system (DSS) tailored to the needs of railroad maintenance safety planning in Germany, identifying the main requirements for the IT solution presented in the following chapters. This chapter begins with section 3.1, "The Safety Planning Process", which methodically dissects present railroad maintenance safety planning methods, giving an in-depth review of current methodologies and identifying potential areas for digital enhancement. Subchapter 3.2 headed "DSS for Safety Planning: Theoretical Model", proceeds to design a DSS theoretical model. Finally, section 3.3, "Overview of Data Sources for the DSS", provides a thorough examination of the numerous data sources that the DSS will rely on. This part is critical for comprehending the data integration and management capabilities required for the DSS to function effectively, ensuring access to correct and up-to-date information for safety planning.

Chapter 4, entitled ***"Implementation of the Theoretical Concept Model Through a Computer Software"***, delves into the practical aspects of transforming the theoretical model of a decision support system (DSS) for work safety in railroad maintenance into a functional computer software. Section 4.1 addresses general aspects regarding the software, including its foundational principles and some considerations regarding the programming. In section 4.2, the chapter provides a detailed exploration of the software's graphical interface and its various functions. This includes 4.2.1, which discusses the creation of a safety plan for general cases, 4.2.2, focusing on safety plan creation for cases with reduced complexity, and 4.2.3, which covers other software features and modules. This chapter is pivotal in demonstrating how the theoretical concepts outlined in Chapter 3 are operationalized in a practical, user-friendly software tool.

Chapter 5 (***"Experimental Research for Testing and Validating the DSS Software"***) presents the empirical phase of the research, where the DSS software is rigorously tested and validated through various experimental research cases. Section 5.1 sets the stage with preliminary considerations, framing the context and objectives of the experimental research. Subsequent sections, 5.2 to 5.5, detail individual research cases, including machine ballast tamping on an open track section, replacement of a railway switch frog, inspection (track walk), and track adjacent vegetation works. Each case provides specific insights into the software's application in different scenarios. The chapter culminates in section 5.6, which assesses the efficiency and effectiveness of the DSS in enhancing work safety in railroad maintenance, providing a critical evaluation of the software's performance in real-world settings.

Chapter 6 (***"Conclusions. Original Contributions. Future Research"***) synthesizes the research findings and outlines the study's contributions to the field. Section 6.1 offers general conclusions, with a focus on the impact of the DSS on work safety in railroad maintenance (6.1.1) and insights into change management and user experience (6.1.2). This is followed by section 6.2, which highlights the original contributions of the research, delineating how the study advances knowledge and practice in work safety and decision support systems. Lastly, section 6.3 proposes directions for future research, suggesting areas where further investigation and development could continue to enhance safety and efficiency in railroad maintenance.

2. The Original Contributions of the Research

This section provides an overview of the doctoral study's novel findings and accomplishments. This section is devoted to defining the distinctive elements of the research that define it in its academic field, emphasizing how it extends or challenges existing knowledge and practices. The emphasis here is on the breakthroughs made, the approaches created, and the practical applications. These contributions not only represent the pinnacle of the PhD program's research, but also highlight the study's potential impact on future academic inquiry and industry practice. The section tries to provide a clear and convincing assessment of the research's importance and role in pushing the boundaries of understanding in its chosen discipline by highlighting these novel contributions.

The first chapter of the thesis provides an original contribution by establishing a clear and thorough research objective, as well as a statement of both subjective and objective arguments for choosing this specific topic. This chapter effectively illustrates the study topic's relevance and urgency, providing a persuasive argument for its importance. It acts as a gateway for readers, providing them with a clear goal and scope, which is necessary for understanding the following chapters.

The author's original contribution is apparent in the in-depth bibliographical study that conveys the debate on work safety in railroad maintenance in the second chapter. The complete review of the railroad maintenance process in Germany, especially the precise insights into various sorts of railway inspections and maintenance activities, demonstrates a thorough mastery of the subject, but also reflects the author's extensive firsthand experience. With over 11 years of expertise in railroad maintenance (acquired through multiple functions held in the infrastructure company DB InfraGO AG in Germany), the author brings a rich, practical perspective that significantly enriches the research. Furthermore, section 2.3's comprehensive study of various safety measures, their benefits, drawbacks, and exclusion criteria add important value to the research. The description of work safety difficulties and causes that leads to the next chapter illustrates the author's capacity to critically assess and synthesize complicated knowledge, connecting theory and practice.

The third chapter of the thesis marks a pivotal point in the research by transitioning from theoretical exploration to the conceptualization of a digital decision support system (DSS) designed for railroad maintenance safety planning in Germany. The meticulous dissection of current safety planning methods and the identification of digital enhancement areas reflect a significant contribution to the field. The development of a theoretical model for DSS in safety planning, detailed in subchapter 3.2, showcases innovative thinking and a new approach to this problem. The identification of the necessary databases for the software is another important original contribution of the author. The comprehensive overview of the identified data sources for the DSS in section 3.3 further exemplifies the author's commitment to creating a robust and practical framework.

Chapter four regards the practical application of theoretical research, where the conceptual model of the DSS for work safety in railroad maintenance is translated into a functional computer software. This chapter embodies the author's innovative approach to problem-solving, bridging the gap between theoretical models and their real-world implementation. The detailed discussion on the software's general aspects, its programming considerations, and the exploration of its graphical interface and functions demonstrates a thorough understanding of both the technical and operational aspects of software development. Particularly noteworthy and a very important original contribution is the adaption of the theoretical concepts defined during the previous chapters of the present doctoral research into a user-friendly software tool, tailored specifically for the unique challenges of railroad maintenance safety.

In Chapter five, the research progresses into an empirical phase, where the originality of the thesis is further underscored through the testing and validation of the programmed DSS software. The chapter's structure, encompassing preliminary considerations and detailed individual research cases, reflects a methodical and comprehensive approach to experimental research. Each case study, ranging from machine ballast tamping on open track sections to the replacement of railway switch frogs, provides specific, data-driven insights into the software’s application in diverse scenarios. The evaluation of the DSS’s efficiency and effectiveness in enhancing work safety in railroad maintenance showcases the author's commitment to empirical rigor and practical relevance.

Several themes from the scope of doctoral research were disseminated during the last years through scientific articles, showcasing the depth of the research. A total of six articles were developed as part of this effort, with four of them being of notable distinction, featured in ISI / ISI Proceedings (Web of Science database). These articles were either presented and discussed in open rounds at international conferences, where they received exposure and feedback from members of the academic community or submitted for publication in various prestigious journals, being peer-reviewed in the process. The inclusion in ISI / ISI Proceedings highlights the research's adherence to rigorous academic standards and its relevance in current scientific discussions, further establishing the significance of doctoral research. A list of the published papers is available in **Annex 12**.

Finally, the original contributions of this PhD dissertation go beyond the discussed academic merits, also serving didactical purposes in the field of higher education. The research findings and insights have been partially incorporated by the author into teaching materials, specifically enriching the curriculum of courses such as “Construction Technology” and “Transportation Infrastructure Construction” at the IU International University of Applied Sciences in Hannover. Since 2022, the author of the thesis has been teaching these courses in the fourth, respectively fifth semester of the “Civil Engineering” study line, using the research findings to provide students with modern ideas and case studies.

3. The research limits

The doctoral research conducted has yielded the development of a practical software tool, a significant advancement in the field of the safety planning process for railway maintenance works in Germany. This solution transforms the safety planning process, improving it from two crucial perspectives: employee safety and the economic efficiency of the infrastructure management company. By automating and digitalizing safety planning, the program not only offers a higher degree of security for on-site workers, but it also optimizes the company's operating procedures. Thus, the research stands out for its immediate relevance and potential to have a real-world impact, embodying a blend of technological innovation, safety commitment, and economic prudence.

Naturally, the tool described in this study is only the first step in a larger journey toward the digitalization and automation of safety planning. Other functions, modules of the software, but also other advancements in this field are either in the implementation phase or present plausible opportunities for strengthening the impacts attained thus far. This constant trend highlights the dynamic nature of digital transformation in safety planning, where continuous improvements and innovations are not only expected but also essential to the practice's evolution. In this domain, the journey toward completely digitalized and automated operations is iterative, indicating a commitment to leverage technological breakthroughs for maximum safety and efficiency outcomes.

A key advancement following the introduction of the FRIDA S tool is the development of a comprehensive workflow encompassing all phases of safety planning. The foundational elements for this workflow have already been established through the companion tool FRIDA S Unternehmer and the feature allowing the import of the created first page of a safety plan into FRIDA S. However, in the version of the digital process presented in this research, the digital support concludes with Part II of the safety plan, leaving Parts III, IV, V, and VI to be completed without digital assistance.

Extending the digital procedure to include Part III, which covers the safety company's detailed planning, would have additional positive consequences. The efficiency and accuracy of information flow might be considerably improved by digitizing this section of the safety plan. Furthermore, extending digital capabilities to Parts IV through VI would be advantageous, notably through the development of an electronic signature mechanism for the parties involved in these sections. Such developments would not only speed up the entire safety planning process, but also strengthen the uniformity and traceability of the paperwork, increasing the overall effectiveness and reliability of the safety planning system.

Regular software upgrades and revisions are required to keep up with any changes in regulations or formal changes to the official safety plan documents. The software described in this thesis was created in conformity with the regulations and official documents in effect at the time the PhD research began. It does not consider any further changes, such as the replacement of documents V03 and V04 with the new versions V10 and V11. As a result, continuous modifications are required to reflect these dynamic legislative and documentary landscapes to assure the software's continued relevance and efficacy.

4. Selective List of References

[1] G. Curtis, W. J. Magee, W. W. Eaton, H.-U. Wittchen, and R. C. Kessler, “Specific fears and phobias,” *British Journal of Psychiatry*, vol. 173, no. 3, pp. 212–217, Sep. 1998, doi: 10.1192/bjp.173.3.212.

[2] Wikipedia, “https://en.wikipedia.org/wiki/List_of_countries_by_rail_transport_network_size.”

[3] “https://www.cia.gov/library/publications/the-world-factbook/rankorder/2121rank.html,” Statista.

[4] WeForum, “https://reports.weforum.org/travel-and-tourism-competitiveness-report-2019/rankings/#series=EOSQ058.”

[5] Pro Mobilität Verkehrsetat, “https://www.promobilitaet.de/fileadmin/user_upload/ProMob_Zahlen_Daten_Fakten_Verkehretat_2022_23.pdf.”

[6] DB Netz AG, “DB Netz AG official webpage.” Accessed: Dec. 31, 2022. [Online]. Available: https://fahrweg.dbnetze.com/fahrweg-de

[7] V. Voicu and G. Caruțașu, “Decision-making Process regarding Work Safety in Railroad Maintenance,” in *Enterprises in the Global Economy*, Constanta: Ovidius University, Nov. 2021.

[8] A. C. Paven, M. Ion, and G. Carutasu, “Decision Support Systems for Buildings Energy Efficiency,” *Acta Technica Napocensis*, vol. 64, no. Special I, pp. 253–260, Jan. 2021.

[9] A. Gorry and M. Scott-Morton, “A framework for management information systems,” 1971. [Online]. Available: https://www.researchgate.net/publication/38008090

[10] P. Keen and M. Scott Morton, “Keen, Scott Morton - 1978 - Decision Systems,” *Addison-Wesley. Reading, MA*, 1978.

[11] S. Alter, *Decision Support Systems: Current Practice and Continuing Challenge*. Reading, MA: Addison - Wesley, 1980.

[12] D. J. Power, “Supporting Decision-Makers: An Expanded Framework,” Krakow, Poland, 2001. Accessed: Nov. 05, 2021. [Online]. Available: http://dssresources.com/papers/supportingdm/PowerEBKSupp.pdf

[13] L. Pérez-Fernández, J. Conde, and M. A. Sebastián, “Decision support system to decrease warranty and intangible costs in automotive industry,” *Procedia Manuf*, vol. 13, pp. 1143–1150, 2017, doi: 10.1016/j.promfg.2017.09.176.

[14] T. M. Alam *et al.*, “A Fuzzy Inference-Based Decision Support System for Disease Diagnosis,” *Comput J*, vol. 66, no. 9, pp. 2169–2180, Sep. 2023, doi: 10.1093/comjnl/bxac068.

[15] K. O. Bazilevych, D. I. Chumachenko, L. F. Hulianytskyi, I. S. Meniailov, and S. V. Yakovlev, “Intelligent Decision-Support System for Epidemiological Diagnostics. II. Information Technologies Development*, **,” *Cybern Syst Anal*, vol. 58, no. 4, pp. 499–509,

Jul. 2022, doi: 10.1007/s10559-022-00484-9.
[16] R. E. Giachetti, P. Damodaran, S. Mestry, and C. Prada, “Optimization-based decision support system for crew scheduling in the cruise industry,” *Comput Ind Eng*, vol. 64, no. 1, pp. 500–510, Jan. 2013, doi: 10.1016/j.cie.2012.08.011.
[17] C. Meier-Hirmer, A. Senée, G. Riboulet, F. Sourget, and M. Roussignol, “A decision support system for track maintenance,” in *Computers in Railways X*, Southampton, UK: WIT Press, Jun. 2006, pp. 217–226. doi: 10.2495/CR060221.
[18] K. Daheshpour, “Network level decision support system to assess railway track maintenance needs,” University of Birmingham, 2018. Accessed: Dec. 24, 2023. [Online]. Available: https://etheses.bham.ac.uk/id/eprint/8164/
[19] A. di Graziano and V. Marchetta, “A risk-based decision support system in local railways management,” *Journal of Rail Transport Planning & Management*, vol. 20, p. 100284, Dec. 2021, doi: 10.1016/j.jrtpm.2021.100284.
[20] W. Górka *et al.*, “Cloud Decision Support System for Risk Management in Railway Transportation,” in *Proceedings of the 14th International Conference on Software Technologies*, SCITEPRESS - Science and Technology Publications, 2019, pp. 475–482. doi: 10.5220/0007837904750482.
[21] J. S. Lee, I.-H. Yeo, and Y. Bae, “A stochastic track maintenance scheduling model based on deep reinforcement learning approaches,” *Reliab Eng Syst Saf*, vol. 241, p. 109709, Jan. 2024, doi: 10.1016/j.ress.2023.109709.
[22] M. C. Leyesa, N. T. Florencondia, M. J. M. Villar, and S. M. A. Galman, “Decision Support System in Environmental, Health and Safety (DSS-EHS) Management Systems,” in *2020 IEEE 12th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment, and Management (HNICEM)*, IEEE, Dec. 2020, pp. 1–6. doi: 10.1109/HNICEM51456.2020.9400126.
[23] N. Vujica Herzog and G. Harih, “Decision support system for designing and assigning ergonomic workplaces to workers with disabilities,” *Ergonomics*, vol. 63, no. 2, pp. 225–236, Feb. 2020, doi: 10.1080/00140139.2019.1686658.
[24] S. Cebi, E. Akyuz, and Y. Sahin, “DEVELOPING WEB BASED DECISION SUPPORT SYSTEM FOR EVALUATION OCCUPATIONAL RISKS AT SHIPYARDS,” *Brodogradnja*, vol. 68, no. 1, pp. 17–30, Dec. 2017, doi: 10.21278/brod68102.
[25] M. Bohanec, I. Vrbanić, I. Bašić, K. Debelak, and L. Štrubelj, “A decision-support approach to severe accident management in nuclear power plants,” *J Decis Syst*, vol. 29, no. sup1, pp. 438–449, Aug. 2020, doi: 10.1080/12460125.2020.1854426.
[26] OpenAI, “ChatGPT.” Accessed: Dec. 30, 2023. [Online]. Available: https://openai.com/chatgpt
[27] I. University of Chicago, “Quillbot.” Accessed: Nov. 25, 2022. [Online]. Available: https://quillbot.com/
[28] V. Voicu and G. Carutasu, “An Overview of Railway Inspections and Work Safety. The Case of Germany,” *Acta Technica Napocensis*, vol. 65, no. Special III, pp. 949–959, Nov. 2022, Accessed: Dec. 24, 2023. [Online]. Available: https://atna-mam.utcluj.ro/index.php/Acta/article/view/1982/1580
[29] V. Voicu and A. Draghici, “Maximizing the use of track possession: a case study on coordinated railway and highway maintenance works,” *Acta Technica Napocensis*, 2024, [Online]. Available: Submitted for publication