Journal of civil engineering and transport **transEngin**

2024, Volume **6** Number **3** **ISSN 2658-1698, e-ISSN 2658-2120**

DOI: 10.24136/tren.2024.011

APPLICATION OF THE STICKY NOTES METHOD FOR SPECIFYING RAMS

Maciej **Nowicki** [1,*], Adrian **Gill** [2]

[1] Łukasiewicz Research Network - Poznan Institute of Technology, Poland

[1] Poznan University of Technology, Faculty of Civil Engineering and Transport, Poland, e-mail: maciej.nowicki@doctorate.put.poznan.pl, https://orcid.org/0000-0002-8973-3096

[2] Poznan University of Technology, Faculty of Civil Engineering and Transport, Poland, e-mail: adrian.gill@put.poznan.pl, https://orcid.org/0000-0002-2655-4584

* Corresponding author

Reviewed positively: 13.09.2024

Information about quoting an article:
Nowicki M., Gill A. (2024). Application of the sticky notes method for specifying RAMS. Journal of civil engineering and transport. 6(3), 37-48, ISSN 2658-1698, e-ISSN 2658-2120, DOI: 10.24136/tren.2024.011

Abstract – One of the fundamentals of the safety management process for specifying RAMS is hazard identification. The regulations defining RAMS requirements allow flexibility in the choice of methods for applying a systematic RAMS management process, including system safety assessments. In practice, however, it turns out that designers are usually limited to tried-and-true, popular and codified methods in the form of, among others, the brainstorming method (for hazard identification) or the FMEA method (for risk analysis). Companies rarely look for other opportunities for alternative approaches to the safety assessment which is usually due to time constraints, competency limitations and fear of change, which, however, can many times produce more effective results despite the original greater effort.

A popular tool used in everyday life for remembering relevant facts are characteristic sticky notes stuck in visible places. Their intuitive use provided the inspiration for the sticky notes heuristic method. In view of the provisions referred to above, which do not impose specific methods to apply a systematic process of RAMS management, the article will present the possibilities of the sticky notes method for the purpose of identifying risks.

The formulated purpose of the article, therefore, is to develop and demonstrate how to use the sticky notes method to identify risks in RAMS specification processes. The study is presented using the example of rail vehicle systems in the form of pneumatic boards.[1]

Key words – hazard identification, pneumatic boards , RAMS, safety assessment, sticky notes

JEL Classification – L62, L92, R41

INTRODUCTION

The specificity of the operation of railroad systems, caused, for example, by the number of entities involved in the implementation of transport processes (including rail carriers, infrastructure managers, siding users, rolling stock manufacturers, rolling stock maintenance management facilities), and above all, the complexity of these systems, pose considerable challenges to entities required to conduct RAMS specification processes (i.e., reliability, availability, maintainability and safety of systems). These challenges generally relate to the ability to leverage human and time resources, especially under changing regulatory conditions. As the authors of the paper [9] point out, the relatively quickly triggered need to implement regulations or adapt to new regulations causes many companies, unable to adapt to new ways of operating, to opt for support by external consulting firms.

However, the scale of use of the mentioned resources (human and/or time) is largely determined by the used (known) methods of hazard identification and risk analysis. Of course, to some extent the choice of these methods is legislatively conditioned i.e. some of them (e.g. FMEA) have been written into safety management or quality management standards, such as, indirectly, Regulation 402/2013 [18] or the IRIS (International Railway Industry Standard) used by manufacturers of railroad vehicles and equipment for these vehicles. On the one hand, such legal

[1] **The research was carried out/financed under the Program of the Ministry of Education and Science "Applied Doctorate" realized in years 2021-2025 (Agreement no DWD/5/0355/2021 as of 01.02.2022)**

entrenchment is advantageous, as it provides the opportunity to refer to legal provisions and easily justify the choice of a particular method The above examples show that, depending on the specifics of the system being evaluated, different methods of threat identification are used, and to different extents. What they have in common, however, is the method of exploring the knowledge of experts or analysts, which is based on the brainstorming technique. Usually, in the subsequent steps of these analyses, the information is subjected to appropriate codification aimed at systematizing it. It should be added that in the context of the RAMS specification of railroad systems, as complex socio-technical systems with specific operating conditions, the methods of hazard identification should, first of all, allow for the following: quick results, ease of application and understanding by personnel at any organizational levels, updating of results and the possibility of correcting errors, versatility in the context of different processes and objects of analysis. These conditions are met by a method called sticky notes (from the entries made on usually yellow and sticky note cards; in everyday life often used to remember important facts, tasks, etc.), which is used practically in project management.

However, the regulations defining RAMS requirements (PN-EN 50126 [13-14]) allow some flexibility in the choice of methods for applying the systematic RAMS management process, including system safety assessment. System safety assessment can be implemented in a number of ways, remaining, of course, within the provisions of the indicated standards.

One of the fundamentals of the safety management process for RAMS specification is hazard identification. For this purpose, especially in the area of hazard identification at the design stage (phase 6. according to the RAMS V model), it is common practice to use heuristic methods, among which the brainstorming technique is by far the most popular. Its popularity is due, among other things, to its ease of application, as confirmed by the author of the article [1] using the aforementioned method for work on developing an innovative concept of noise protection solutions for the Swedish high-speed railroad, or the work [2] devoted to risk management in the Ahwaz urban railroad project. Brainstorming is also one of the oldest heuristic methods described, as the first publications date back to the 1950s as evidenced by the entry [3]. There are also many variations of brainstorming such as: Philips 66 Buzz Session, Method 635 (brainwriting) or an electronic version of brainstorming *brainnetting*.

In opposition to the mentioned method, one can find numerous studies pointing out the disadvantages of brainstorming, as indicated, among others, by the authors of the article [4] justifying that groups using this method are less productive than, for example, those using the nominal group technique (NGT), the practical possibilities of which were examined, among others, by the author of the article [5]. The nominal group technique is usually used in situations where there is a danger of the rest of the group being dominated by participants with strong personalities.

Another heuristic method for identifying risks is the Delphi method, which was described as early as 1963 in a publication [6]. This method makes it possible to come to a consensus when there are opposing opinions among experts. Examples of its large-scale application include the evaluation of the development of freight transport of the Finnish railroad, which involved as many as 52 local experts, as summarized by the authors of the article [7]. The Delphi method is also used among applications of new technologies, an example of which is the study of the feasibility of operating autonomous trains (ATOs) in multimodal transportation in Europe [8].

The above examples show that, depending on the specifics of the system being evaluated, different methods of threat identification are used, and to different extents. What they have in common, however, is the method of exploring the knowledge of experts or analysts, which is based on the brainstorming technique. Usually, in the subsequent steps of these analyses, the information is subjected to appropriate codification aimed at systematizing it. Unfortunately, in cases of their practical use in the context of the RAMS specification of railroad systems (as complex socio-technical systems with specific operating conditions), they turn out to be either too simple and subjective or, on the contrary, relatively complex, requiring significant human and time resources. We consider that for the purpose of specifying RAMS, hazard identification methods should be characterized by the following features: quick results, ease of application and understanding by personnel at any organizational levels, ability to update results and correct errors, universality in the context of different processes and analysis objects. We also think that these conditions are met by a method called sticky notes (from the entries made on usually yellow and sticky note cards; in everyday life often used to remember important facts, tasks, etc.), which is used practically in project management.

We assume, therefore, that it is possible to suitable use the sticky notes method of evaluation to technical systems in the context of the RAMS specification.

We would like to test this and demonstrate it on a real object, especially since there is a lack of examples of its practical use in the literature as well as in known industry applications.

Therefore, the purpose of this article is: to develop and demonstrate how to use the sticky notes method (hereafter SNM) to identify risks in RAMS specification processes. The study is presented using the example of rail vehicle systems in the form of pneumatic boards.

1. THEORETICAL INTRODUCTION

According to the authors [17], the ubiquitous sticky notes are one of the most widely used ways of visually supporting design, but without a codified, mandatory methodology for use, which is dictated, among other things, by its intuitiveness, which is one of the advantages of the present method.

The SNM methodology described in this article is an adaptation of the method presented in the work [9], applied to the identification of risks occurring during the replacement of a vehicle's power pack system as part of maintenance activities performed by an ECM (entity in charge of maintenance).

SNM is a form of collecting and organizing the knowledge of those involved in different areas of the process based on the concept of "expert history." Written on a piece of paper, the story is usually a short sentence written according to a scheme in accordance with Figure 1 below. The last section in square brackets "For what purpose" is optional and is a kind of elaboration of the indicated activity.

A common practice to systematize expert information records is to use notation in accordance with the HAZOP method [16].

An important factor that determines the results of the work is the way the cards are arranged in the next step, called mapping [10]. The importance of this step is also confirmed by the authors of a paper [17] looking in detail at the movement of cards. They analytically studied the approach to the mapping stage by identifying several types of card movements performed by a team of experts related to association formation, grouping and building partial structures of the SNM map.

Details of the developed SNM method are presented in the following subsections.

1.1. TEAM SELECTION

To ensure the completeness of the results obtained, it is necessary to include among the workshop participants people who are variously responsible for the processes to be evaluated, which will allow: faithfully reproduce the chronology of the work, strengthen the sense of shared responsibility for the implementation of activities in their areas (psychologically important), and provide access to a broader context about the process.

Experience shows that workshops should be attended by no more than five people, as it is difficult to keep a larger group focused while discussing the substance of the case. In a situation where the process is more complicated and more experts need to be present, the spherical aquarium method can be used, as described in the literature [10]. In this method, the room in which the workshop is conducted is divided into two parts. The inner part, or the so-called "aquarium," consists of a whiteboard, the workshop leader and participants who can actively engage in discussions. Other participants in the outer part can only observe the discussion. Only a limited number of participants (three to five) can be present in the aquarium; if a participant from the outer part wants to join the discussion, one of the participants from the inner part must leave [9].

1.2. PREPARATION AND MAPPING OF STICKY NOTES

At the meeting, each workshop participant is given a stack of sticky notes. On these slips of paper, participants write their stories according to the diagram shown in Figure 1.

It is important to make only one entry on each card. The level of detail required for descriptions of activities or the scope of the analysis should not be specified and participants should write on the cards what they consider important. The person leading the workshop (moderator) collects all the notes and, together with the participants, places them on the board.

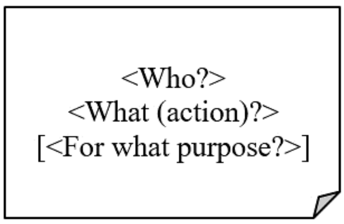

Fig. 1. Sticky notes filling template (own elaboration)

The notes are pasted in groups, which first can be divided by the responsibilities for each task (the results of the obtained information <Who?> according to the scheme in Figure 1.) which will allow them to be properly assigned to the phase based on the V RAMS model and then chronologically in the order of doing the work in the process.

From a practical point of view, it is important to leave space between the rows of the above groups for the results of later "questioning" of the map. The activities of each expert are placed chronologically from left to right. Activities that are somehow related to each other (activities performed together or in a specific sequence) or activities that are mutually exclusive should be marked with a pen/marker directly on the board in a symbolic way indicating the relationship between the notes.

Repeated or more general descriptions of activities should not be removed, but should be pasted one above the other, providing important information, for example, on prioritizing areas of concern. In addition, this helps avoid the impression that one participant is "better" than another based on the greater number of cards kept on the board. During mapping, new cards can also be added to describe activities that were not completed at the initial stage. The essence of the method is also mutual discussion of the adequacy of the described scenarios which is carried out according to the principles described in section 1.3.

Alternatively, the above activities can also be carried out online using, for example, a Microsoft office 365 environment allowing file sharing among experts with graphical support from, for example, Note Canvas software. Such a solution allows more freedom in the timing of filling out virtual cards by participants, which can be important when it is difficult to set a convenient time to organize a workshop. The topic of digital cards has been addressed by the authors of an article [11] comparing desktop and remote use of SNM. The article found no significant differences in effectiveness between digital and conventional approaches in the number of notes created or in the way participants collaborated, among other things. When using SNM digitally, care must be taken to ensure that team members do not see others' evaluations until their own evaluation is complete, since the goal of the analysis is to identify independent observations free of mutual influence.

1.3. Commenting on the developed map

The developed sticky notes "map" is the basis for the preparation of further guidelines, so it is important that it reflects the actual process with its variability as closely as possible. Therefore, it is good practice to provide relevant information about the conditions/ environment in which the listed activities are carried out.

From experience, experts often tend to overlook possible problems unless they themselves have experienced them in the past. To supplement the map with this type of information, it is suggested to use keywords from the HAZOP method for each of the map's elements to stimulate discussion and make it more systematic. A set of basic HAZOP (Hazard and Operability Study) keywords is included in the standard [16] and in publications using the method.

The last step of the proposed method allows you to check the results obtained and informs you about the process based on the map created. When reviewing the full story, it is also important to pay attention to the connections/relationships (such as a specific order) between activities. All workshop participants should agree that the developed story, correctly describes the analyzed process.

2. Object of analysis

The RAMS specification object is pneumatic boards, which are used in all types of rail vehicles, mediating the control of brake systems, the supply of compressed air to these systems, and the distribution of compressed air for auxiliary vehicle systems (e.g., the supply of parking handbrake status indicators or door locking and closing devices). In addition, transducers are built into the arrays to measure pressures in, for example, the supply and main lines, brake cylinders, and auxiliary reservoir.

Therefore, for the purpose of this article, the holistic process of development of an exemplary type of pneumatic board in the form of a cab brake board type 79ZW 94-6 at the stages of: design, production, validation and operation (according to the V RAMS model) was selected.

Brake board type 79ZW 94-6 is an assembly (consisting of electrical, electro-pneumatic and pneumatic apparatuses), designed for installation in the pneumatic system of a traction unit.

Cabin brake board type 79ZW 94-6 has the shape of a flat rectangular body, to the face of which pneumatic and electropneumatic apparatuses are attached. Pneumatic connections of the board are also located on this surface. The upper part of this body is a box with a cover and electrical connections of the board housing the board's power supply, ordinary strip connectors with built-in miniature relays, S32 type controller modules, and electropneumatic valves, pressure transducers and pressure switches cooperating with this controller.

The pneumatic parameters of the type 79ZW 94-6 array are as follows [12]:

Table 1. Selected basic parameters of pneumatic boards (own elaboration)

No.	Parameter	Description
1.	Highest pressure in the supply line	1000kPa
2.	Air purification equipment built in the board	Cyclone with dehydrator on supply line
3.	PN brake functions available through the board	Standby, service braking (8 braking steps), emergency braking, cut-off of the board brake control system from the main cable
4.	EP - B brake functions available through the board	Brake loosened or one of eight braking stages
5.	Possible states of the parking brake	Brake loosened, braked or off
6.	Highest pressure in parking brake spring actuators	Equal to the board supply pressure
Electrical parameters of the boards		
7.	Rated supply voltage of the board	24V DC
8.	Board power supply type	24V 24A
Working conditions		
9.	Operating temperature	-30 + 50 C
10.	Place of work	The driver's cab or the immediate vicinity of of this cabin
11.	Work position	Vertical

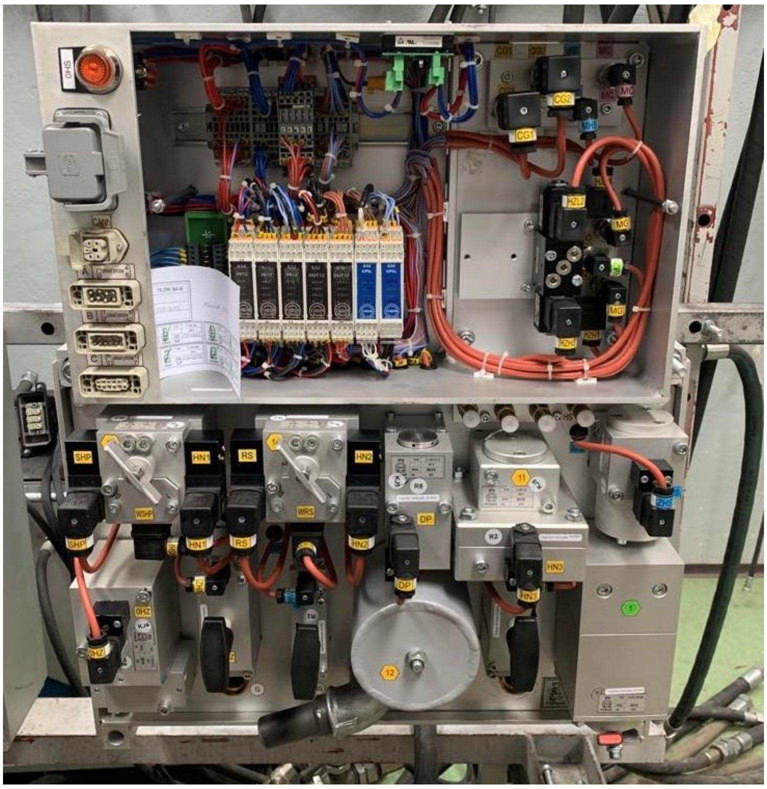

Fig. 2. Pneumatic board 79ZW94-6 during maintenance work (own drawing courtesy of PIT-Industry)

The photograph below shows the type 79ZW 94-6 pneumatic board in question at the maintenance phase.

The component described above is manufactured by PIT Industry, a company with many years of experience in the field of rail vehicle braking systems. PIT Industry relies on its own research and technical solutions to design and develop technologically advanced rail vehicle brake control systems, so due to their expertise, all participants in the workshop described in the next section are employees of the above-mentioned company.

3. GUIDELINES AND RESULTS OF APPLYING STICKY NOTES TO THE HAZARD IDENTIFICATION PROCESS IN SPECIFYING RAMS

As indicated in the introduction of this article, one of the fundamentals of the safety management process for specifying RAMS, is hazard identification. The result of the hazard identification process should be a formulated hazard. However, in order for such a formulation to be useful in further stages of risk management, it should include the following elements (according to Section 7.4.2.1. of the RAMS standard [13]):

- identification of the sources/causes of the risk formulation, e.g. component, subsystem or system failures, human error, etc.,
- adverse events that may lead to losses during system operation and maintenance,
- losses (effects) associated with undesirable events - from the point of view of railroad operations, losses can mean damage to passengers, employees or members of the public, damage to the environment etc.,
- existing control measures to control and reduce the occurrence of an adverse event.

In addition, the identification of risks can lead to the formulation of risks from so-called systematic errors, among others, in the system design phase, human errors, errors in instructions, and so-called random errors resulting primarily from fatigue, environmental overloads, etc., according to RAMS requirements [13].

Given that human error is now considered the most important source of accidents or incidents in safety-critical systems (as emphasized by the authors of the article [19], among others), the SNM is intended to support the identification of the mentioned systematic errors.

Therefore, to achieve the above objectives of hazard identification in the RAMS specification processes of pneumatic boards, the SNM method was used in accordance with the methodology presented in para. 2. because the aforementioned method works well in predicting future phenomena, relying on creative thinking and logical combinations.

The proposed method of collecting knowledge from experts was used during cyclical meetings held at the Lukasiewicz Research Network - Poznan Institute of Technology, the results of which are presented in the following subsections.

3.1. SELECTION OF WORKSHOP PARTICIPANTS

In order to ensure the completeness of the results obtained, it was necessary to include among the participants in the hazard identification workshop those who are variously responsible for the processes under analysis. Therefore, for the purpose of RAMS specification, representatives of specialists involved in the various stages of development of the object of analysis (pneumatic boards) were selected, i.e. the stages of design, production, validation and operation (according to the RAMS V model).

Ultimately, the workshop was attended by five people working in the positions of:

- a specialist from the design department of pneumatic systems,
- 2 specialists from the production department (mechanic and electrician),
- a specialist from the quality control department,
- service technician,

thereby forming an interdisciplinary team of experts.

All participants in the workshop have many years of experience in the work performed which was an important criterion in the selection of the team.

Moderation of the meetings was carried out by the author of this article not related to the process of design and manufacture of pneumatic boards having, however, experience in the implementation of safety assessments and RAMS analyses.

The duration of the workshop was not limited in advance, however, in order to maintain operational fluidity, the various stages of the workshop did not last longer than 1.5 hours.

At the beginning of the workshop, all participants were informed of the purpose of the meetings held, while emphasizing that the work carried out is not intended to assess their competence and verify the correctness of their actions in accordance with the procedures in force. In particular, the potential effect of the team's activities could be the modification of existing procedures, which also strengthened the sense of influence of their work on the final production result, which is pneumatic boards.

3.2. PREPARATION AND MAPPING OF ACTIVITY DESCRIPTIONS

Due to the availability of the expert team, the workshop was implemented in several stages:

- collecting information on cards in a hybrid form: service and design department in a remote form using the Sharepoint platform of the environment and OneNote running within Microsoft Office 365, while production and quality control staff in a desktop form, which was also influenced by access to the aforementioned supporting software.

– mapping and commenting in desktop form.

A facilitator was responsible for coordinating the aforementioned activities.

As was the case with the authors of the article [9], the participants had no problem understanding the task, which confirms the intuitiveness of the SNM. As expected, experts had doubts about the level of decomposition of activities and their detail. In the first stage, each participant was able to mention and describe from about 10 to 20 activities leading to their completion of the work within their stage according to chronology:

1. design stage,
2. production stage,
3. the quality control stage,
4. service stage.

Collected in the described hybrid form, the cards were taped to the board in chronological order during the stationary meeting.

3.3. Questioning the developed map

In order to be more transparent, this article will present an excerpt of the results of the work on the quality control stage, as shown in Figure 4.

Supplementary information:

– cards containing the works arranged chronologically according to the order of their execution from left to right,
– cards stuck in lower rows detail the activities stuck above them,
– gray slips mark additional conditions related to the activities performed.
– Particular attention should be paid to the cards marked in red because thanks to them the initial sources of risks are formulated, on the basis of which in the next step are identified risks at the level of the system under consideration (system under consideration) and risks at the level of the railroad system (railroad system level). The relationship between the various components of such a chain of events and states according to the guidelines of the RAMS standards, is shown schematically in Figure 3.

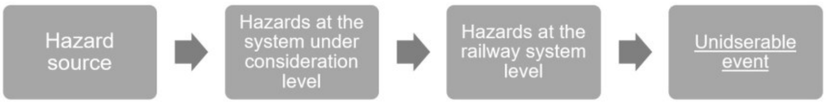

Fig. 3. Evolution of the source of the threat assuming consideration of the threat at two levels according to [14]

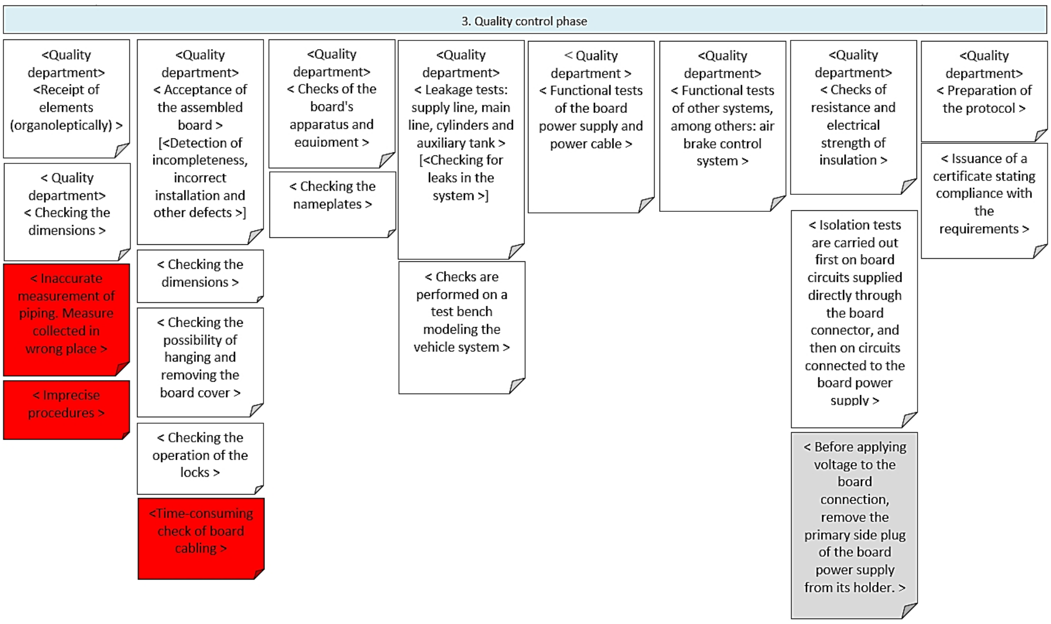

Fig. 4. Excerpt from sticky notes results of quality control stage (own elaboration)

In *several* situations, it was only in the course of sticking the notes, it became apparent that certain activities had not been identified at the first stage, which was achieved by, among other things additional clarifying questions by the facilitator, e.g.:

– *What is the result of the work described?*

With this question, the activities of drawing up a protocol in accordance with the model in the Annex to the WTO (Technical Acceptance Conditions) and, consequently, issuing a certificate stating that the pneumatic board meets the requirements (last row of Figure 4.). The situation presented here is due to the fact that some of the activities performed by the experts were obvious from their perspective to carry out constituting an integral summary of their activities in a documented form. On the basis of the discussion, we unanimously came to the conclusion that the indicated duties are an important part of the process, and the lack of their specification in the first iteration may be a manifestation of routine, that is, one of the most serious causes of human error resulting from the implementation of repetitive activities.

The group of errors/human factors is devoted to a whole set of human reliability analyses. (HRA - Human Reliability Analysis). Section 5.6.4 of the RAMS standard [14] defines human factors as anatomical, physiological and psychological aspects of humans. According to the authors of the article [19], during the operation of transportation systems such as trains, ships, aircraft and motor vehicles, about 70-90% of accidents are directly or indirectly due to human error, and according to the same authors, with the development of technology, the reliability of transportation systems has increased in recent decades, while human reliability has remained unchanged over the same period.

The above treatment remains consistent with the provisions of para. 11.2. [9] indicating that causal analysis should also identify plausible human error, for which the SNM in question works, as confirmed by the sample described above, among others.

– *How the activities in point are carried out?*

This question made it possible to detail some of the identified work (resulting in more column rows). As expected, experts had doubts about the level of decomposition of activities and their detail, which was confirmed by sometimes overly general entries constituting the top row. The moderator's task, therefore, was to make some of the tasks more specific, which was achieved, among other things, thanks to the above question.

An additional but expected effect of this question was also the identification of sources of risk, in the form of, among other things, inaccurate measurements during the reception of details in the form of piping. The reason for the error was that the measure was collected in the wrong place. According to WTO documentation (Technical Acceptance Conditions), dimensions are checked with gauges or measuring instruments. Accuracy corresponds to the manufacturing tolerances of the individual components. Taking measurements with instruments gives some freedom in selecting the place of measurement, which can potentially be a source of danger. The described situation does not pose a threat to the final quality of the pneumatic board, but it can slow down the work at the production stage if there is insufficient precision in the manufacture of its individual components.

In addition, in the area described above, the use of keywords from the HAZOP method (according to the standard [16]) was also applied to stimulate discussion. This initiative did not affect the discussed scope at the quality control stage, however, it proved effective, for example, at the production stage by identifying, among other things, potential forms of damage to the pneumatic board.

– *How are the activities in question implemented?*

The acceptance work of the object of analysis is carried out in a systematic manner based on the relevant documentation in the WTO, which allows to confirm the quality of manufactured components. One of the elements of the checks is the verification of the correctness of the installation of the wiring of the pneumatic board. With the appropriate sequence of checks, it is possible to examine the correct functioning of the electrical system of the assessed object. The experts noted the fact of the relatively time-consuming process of identifying the sources of potential errors occurring in the electrical system, which may be the basis for considering the implementation in the existing identification mechanism of an additional diagnostic element, which was unanimously proposed by the workshop participants. Such a procedure will not affect the effectiveness of the detected errors, since functional tests on the modeled bench are a sufficient tool. However, the experts' proposal can significantly affect the time of searching for the sources of arising nonconformities, optimize the process, which ultimately has the potential to generate noticeable savings from the business point of view.

In the end, after the additions described above, all workshop participants agreed that the developed process map, correctly represents the actual process, which was the basis for completing the work by achieving the goal.

The excerpt from the results of the work on the quality control stage discussed above is shown in Figure 4. The use of SNM allowed Identification of systematic errors resulting from, among other things:
- failure to apply the provisions of instructions and procedures,
- haste in the work in progress,
- routine in the case of repetitive activities.

The experts participating in the workshop expressed their willingness to continue working together in similar initiatives, which confirms their awareness of their responsibility for the quality of the final pneumatic board product, and is also indirectly a vote of confidence in the proposed SNM method.

CONCLUSIONS

As mentioned earlier, the complexity of railroad systems as well as the specifics of their operation place serious demands on RAMS specifiers. These particularly concern the use of available human and/or time resources. The reason for this is, on the one hand, the scope of the specification, including the issues of reliability, availability, maintainability and safety of the systems throughout the life cycle of the systems, and on the other hand, the use by those required to specify RAMS of methods that are known, but not always rational in terms of the mentioned resources. Although the approach based on standard methods is reasonable, because it gives at least the possibility to refer to legal provisions and easily justify the choice of a particular method, it somehow limits the desire to look for other, non-standard methods. It was noted that such a situation creates a certain paradox - the desire/necessity to use certain methods with insufficient potential for their implementation. In the long run, it may prove not only problematic, but raise doubts about the reliability and usefulness of the results obtained.

Therefore, attention was paid to the possibility of applying non-standard but, above all, very intuitive methods of analysis, especially since the regulations defining RAMS requirements allow some freedom in their selection.

As an area of analysis with the greatest possible benefits of applying such methods, the process of hazard identification was chosen. This is because the quality of results obtained in other RAMS processes depends on the results of its implementation. It is not without reason that this process is referred to as the heart of risk management.

The analysis of the literature in this area has indicated that, depending on the specifics of the system being evaluated, different methods of hazard identification are used, and to varying degrees. What they have in common, however, is the method of exploring the knowledge of experts or analysts, which is essentially based on the brainstorming technique.

In the context of the RAMS specification of railroad systems, hazard identification methods should, first of all, allow quick results, ease of application and understanding by personnel at any organizational level, updating of results and possibility of correcting errors, but also versatility in the context of different processes and analysis objects. These conditions are met by SNM, with the additional characteristic of being highly intuitive.

SNM is practically used to support design processes, but it has also been applied to the identification of hazards occurring during the replacement of the power pack system of rail vehicles as part of maintenance activities performed by the ECM (entity in charge of maintenance). However, the need was recognized to develop and present a method for its application to the identification of hazards in the RAMS specification processes of the systems of these vehicles, especially since this requires appropriate adaptation of the method. This was adopted as the purpose of this article. Pneumatic boards, which are used in all types of rail vehicles mediating the control of brake systems, the supply of compressed air to these systems, and the distribution of compressed air for auxiliary vehicle systems (e.g., the supply of parking handbrake status indicators or door closing and locking devices), were chosen as the object of analysis.

First, a description of the object of analysis - a pneumatic board in the form of a cabin brake board type 79ZW 94-6 - was made. It should be pointed out that the correct description of the object (so-called system definition) is a separate, important issue in RAMS specification. Next, the guidelines and results of applying SNM to the process of hazard identification in RAMS specification are presented. The adaptation of SNM in this regard requires taking into account the specific approach to hazards involving, among other things, their division into hazards at the level of the analyzed system and hazards at the level of the railroad system. In addition, it is necessary to formulate hazards from so-called systematic errors, among others, in the system design phase, human errors, errors in instructions, and so-called random errors resulting primarily from material fatigue, environmental overloading, etc. Next, guidelines for the selection of workshop participants were presented. In order to ensure the completeness of the results obtained, it is necessary that the participants of the hazard identification workshop include people who are variously responsible for the processes being analyzed.

Therefore, for the purpose of RAMS specification, representatives of specialists involved in the various stages of development of the object of analysis (pneumatic boards) were selected, i.e. the stages of design, production, validation and operation (according to the RAMS V model). In the end, the workshop was attended by five people working in the following positions: a specialist from the design department of pneumatic systems, two specialists from the production department (mechanic and electrician), a specialist from the quality control department, a service technician. Equally important is the preparation and mapping of activity descriptions (presented in subsection 3.2). Due to the availability of the expert team, the workshop was implemented in several stages: collecting information on cards in a hybrid form: service and design department in remote form using the Sharepoint platform of the environment and OneNote running within Microsoft Office 365, while production and quality control employees in desktop form, which was also influenced by access to the above-mentioned supporting software, mapping and commenting in desktop form. The last of the SNM stages presented is the issue of so-called questioning of the developed map. In several situations, only in the course of the process of sticking notes it turned out that certain activities had not been identified at the first stage, which was achieved, among other things, thanks to additional clarifying questions asked by the facilitator. This identified, among other things, the activities of drawing up a protocol in accordance with the model in the WTO Annex (Technical Acceptance Conditions) and, consequently, issuing a certificate stating that the pneumatic board meets the requirements (last row of Figure 4.).

The use of SNM allowed the identification of systematic errors arising from, among other things:

- failure to apply the provisions of instructions and procedures,
- haste in the work in progress,
- routine in the case of repetitive activities.

which was possible thanks to the proper selection of the team of experts. The results obtained inspired to formulate a rather obvious conclusion that the effectiveness of achieving the stated goal in SNM depends largely on the group of specialists invited to cooperate. With the above in mind, in the next step one can consider changes in the personnel of those participating in the workshop, e.g. by people with less experience which should allow to look for errors resulting from, for example:

- difficulties arising from adaptation in relation to new activities caused by modifications to production processes,
- lack of experience, which is especially true for newly hired employees,

which is a potential direction for SNM development.

The proposed adaptation of the SNM was used during regular meetings held at the Lukasiewicz Research Network - Poznan Institute of Technology. The results are presented in the form of a diagram/ table for the quality control stage.

The presented method and the way it is applied is not intended to replace those currently in use, but to complement the resources of available tools for RAMS specification.

Summarizing the work performed, it can be concluded that it is possible to identify risks at subsequent life stages of technical systems (including rail vehicle systems) using SNM, which confirms the adopted hypothesis.

ABBREVIATIONS

1. **RAMS** - Reliability, Availability, Maintainability, Safety
2. **SNM** - Sticky notes method
3. **WTO** - Warunki Techniczne Odbioru
4. **FMEA** - Failure Modes and Effects Analysis
5. **HAZOP** - Hazard and Operability Study
6. **HRA** - Human Reliability Analysis
7. **ECM** - Entity in charge of maintenance

ZASTOSOWANIE METODY STICKY NOTES NA POTRZEBY SPECYFIKOWANIA RAMS

Jednym z fundamentów procesu zarządzania bezpieczeństwem na potrzeby specyfikowania RAMS jest identyfikacja zagrożeń. Regulacje prawne definiujące wymagania RAMS dopuszczają swobodę w doborze metod stosowania systematycznego procesu zarządzania RAMS, z oceną bezpieczeństwa systemu włącznie. W praktyce okazuje się jednak, że projektanci ograniczając się zwykle do sprawdzonych, popularnych i skodyfikowanych metod w postaci m.in. metody burzy mózgów (na potrzeby identyfikacji zagrożeń) lub metodę FMEA (w celu analizy ryzyka). Przedsiębiorcy rzadko poszukują innych możliwości alternatywnego podejścia do szeroko pojętej oceny bezpieczeństwa co zwykle wynika z ograniczeń czasowych, kompetencyjnych oraz obawy przed zmianami, które jednak wielokrotnie mogą dawać bardziej efektywne wyniki pomimo początkowego większego nakładu pracy.

Popularnym wykorzystywanym w życiu codziennym narzędziem do zapamiętywania istotnych faktów są przyklejane w widocznych miejscach charakterystyczne kartki samoprzylepne. Ich intuicyjne stosowanie stanowiło inspirację do powstania metody heurystycznej sitcky notes. W obliczu przywołanych powyżej zapisów, nie narzucających konkretnych metod do stosowania systematycznego procesu zarządzania RAMS, w artykule zaprezentowane zostaną możliwości metody sticky notes na potrzeby identyfikacji zagrożeń.

Sformułowanym celem artykułu jest zatem opracowanie i przedstawienie sposobu wykorzystania metody sticky notes do identyfikacji zagrożeń w procesach specyfikowania RAMS.

Opracowanie przedstawiono na przykładzie systemów pojazdów szynowych w postaci tablic pneumatycznych.

Słowa kluczowe: identyfikacja zagrożeń, tablice pneumatyczne, RAMS, ocean bezpieczeństwa, sticky notes.

REFERENCES

[1] Uppenberg C., Jonsson E. (2018). Innovative noise protection solutions for Sweden's first high speed railway. Master Thesis, Credits Degree project for a Master of Science in Master Programme in Management of Logistics and Innovation.

[2] Tavakolan M., Mohammadi A. (2017). Risk management workshop application: a case study of Ahwaz Urban Railway project, *International Journal of Construction Management*. 260-274. https://doi.org/10.1080/15623599.2017.1325112.

[3] Osborn, A. F. (1953, rev. 1957, 1963). Applied imagination: Principles and procedures of creative problem-solving. New York: Charles Scribner's Sons.

[4] Mullen B., Johanson C., Salas E. (1991). Productivity Loss in Brainstorming Groups: A Meta-Analytic Integration Basic and Applied Social Psychology. 12, 3-23. https://doi.org/10.1207/s15324834basp1201_1.

[5] Islam R. (2010). Group decision making through nominal group technique: an empirical study, Journal for International Business and Entrepreneurship Development. 5(2) 134 – 153. DOI: 10.1504/JIBED.2010.036998.

[6] Dalkey N., Helmer O. (1963). An Experimental Application of the Delphi Method to the Use of Experts Management Science. 9, 458-467.

[7] Mäkitalo M., Hilmola O.P. (2010). Analysing the future of railway freight competition: A Delphi study in Finland Foresight. 12(6), 20-37. DOI: 10.1108/14636681011089961.

[8] Djordjević B., et al. (2023). Determinants of autonomous train operation adoption in rail freight: knowledge-based assessment with Delphi-ANP approach, Soft computing in decision making and in modeling in economics. 27, 7051–7069. DOI:10.1007/s00500-023-07966-8.

[9] Smoczyński P., Gill A., Motyl M., Babiak A. (2021). How to do it with sticky notes: a method for exploring expert knowledge to prepare guidelines for practice in railway vehicle maintenance. *Transport Problems*. 16(1), 153–164. DOI: 10.21307/tp-2021-013.

[10] Patton, J. (2014). *User Story Mapping: Discover the Whole Story, Build the Right Product*. O'Reilly Media.

[11] Jensen M.M., Thiel S. K., Bodker S. (2018). Physical Versus Digital Sticky Notes in Collaborative Ideation, Computer Supported Cooperative Work (CSCW). 27, 609–645.

[12] 79ZW94-6 0159-1 (2015). Technical and operating documentation of cabin brake boards type 79ZW 94-6. Institute of Rail Vehicles TABOR in Poznań.

[13] PN-EN 50126-1:2018-02. *Zastosowania kolejowe - Specyfikowanie i wykazywanie niezawodności, dostępności, podatności utrzymaniowej i bezpieczeństwa (RAMS)*. Część 1: *Proces ogólny RAMS*. 01.02.2019.

[14] PN-EN 50126-2:2018-02. *Zastosowania kolejowe - Specyfikowanie i wykazywanie niezawodności, dostępności, podatności utrzymaniowej i bezpieczeństwa (RAMS).* – Część 2: Sposoby podejścia do bezpieczeństwa.

[15] PN-EN 50129:2019-01. *Zastosowania kolejowe - Systemy łączności, przetwarzania danych i sterowania ruchem - Elektroniczne systemy sterowania ruchem związane z bezpieczeństwem*.

[16] PN-EN 61882. *Badania zagrożeń i zdolności do działania (badania HAZOP) - Przewodnik zastosowań*, Polski Komitet Normalizacyjny. 2016.

[17] Christiansen B.T., Abdilgaard S.J. (2021). Kinds of 'moving' in designing with sticky notes. *Design Studies Copenhagen Business School*. 76. https://doi.org/10.1016/j.destud.2021.101036

[18] Rozporządzenie Wykonawcze Komisji (UE) nr 402/2013 z dnia 30 kwietnia 2013 r. w sprawie wspólnej metody oceny bezpieczeństwa w zakresie wyceny i oceny ryzyka i uchylające rozporządzenie (WE).

[19] Felice F., Petrill A. (2011). Methodological Approach for Performing Human Reliability and Error Analysis in Railway Transportation System. *International Journal of Engineering and Technology*. 3(5), 341-353.

[20] Zhang Y., Fom D.D. (2022). Hazard identification and risk assessment of Abuja rail mass transit, Transportation Safety and Environment. 4(2).

[21] Li Q., Zhang Z., Peng F. (2021). Identification for Railway Accident Prevention: Complex Network-Based Model Development and Comparison, Entropy.

[22] Nedeliakova E., Hranicky M.P., Valla M. (2022). Risk identification methodology regarding the safety and quality of railway services, Production Engineering Archives. 28(1), 21-29.

[23] Leitner B. (2017). A General Model for Railway Systems Risk Assessment with the Use of Railway Accident Scenarios Analysis Procedia Engineering. 187, 150 – 159.

[24] Wang, J., et al. (2023). Data driven lightning related failure risk prediction of overhead contact lines based on Bayesian network with spatiotemporal

fragility model. *Reliability Engineering and System Safety*. 231. https://doi.org/10.1016/j.ress.2022.109016.
[25] Vincoli, J.W. (2014). *Basic Guide to System Safety*, Third Edition [Internet]. John Wiley & Sons Inc. https://doi.org/10.1002/9781118904589.
[26] Macdonald D. (2004). *Practical Industrial Safety, Risk Assessment and Shutdown Systems for Industry* [Internet]. Elsevier/Newnes, Oxford, UK and Burlington, MA.
[27] Aven T. (2015). Risk Analysis. John Wiley & Sons. https://doi.org/10.1002/9781119057819.
[28] Gill, A., Kadziński, A. (2016). Hazard identification model. *Proceedings of 20th International Scientific Conference Transport Means* (5-7 October 2016, Juodkrante, Lithuania), Kaunas University of Technology. 885–900.
[29] Carter G., Smith A.D. (2006). Safety Hazard Identification on Construction Projects. *Journal of Construction Engineering and Management*. 132(2). DOI: 10.1061/(ASCE)0733-9364(2006)132:2(197).
[30] Wang L. C. (2004). Hazards Identification Model for Rail Rapid Transit Accidents. *Journal of Mine Science and Technology*. 12, 78-85.
[31] Schulze J. (2010). Improvement of Hazard Identification in Railway Software. Master's Thesis in Secure and Dependable Computer Systems. Chalmers University of Technology. Goteborg
[32] Hwang J. G., Jo H. J. (2013). Hazard Identification of Railway Signaling System Using PHA and HAZOP Methods. *International Journal of Automation and Power Engineering* (*IJAPE*).