

Open Innovation and Crowdsourcing: Challenges and Opportunities for Serbian Railways

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Abstract—The paper presents research that proposes prototype solutions based on open innovations, the Internet of Things, and crowdsourcing, which can increase traffic safety and reduce human casualties and material damage. The paper's authors conducted the research in cooperation with the Faculty of Organizational Sciences (FON) students in Belgrade and railway experts. FON students were presented with seven typical situations on the railway in Serbia. Traffic safety is often endangered, with human casualties and significant material damage, and the cause of these negative phenomena and accidents is not the railway. Traditional technical-technological solutions to these traffic problems to increase safety are extremely expensive and functionally complex, so they cannot be comprehensive, universal, and global. After the research, prototype solutions based on crowdsourcing principles were proposed, based on open innovations and the Internet of Things, to reduce the number and consequences of such characteristic situations on the railway. The research results confirm that open innovations based on crowdsourcing and the Internet of Things can increase safety in specific segments of railway traffic.

Keywords - Open innovation, railways, crowdsourcing, Internet of Things, transport, prototype

I. INTRODUCTION

There are typical situations in the railway traffic in Serbia. Safety and accidents with human victims and significant material damages are often endangered, which causes a negative attitude of public opinion towards this traffic system. At the same time, the cause of these negative phenomena and accidents is not the railway.

Such situations in railway traffic occur along with the entire territory of Serbian railways. They are numerous, from extraordinary events at road crossings, through accidents due to electric shocks from the contact network above the track and walking on the open railway, to the theft of railway parts and equipment. In a situation when, after several decades of insufficient investments in the railway, a comprehensive process of modernization of the railway infrastructure and rolling stock in Serbia has begun, such cases and the consequences they bring with them have highly negative connotations.

The stated typical situations on the railway can be solved with traditional and modern technical-technological solutions. However, they are costly and functionally complex, so such cases cannot be resolved uniquely on the entire territory of Serbian railways.

The development of the Internet of Things has enabled the wider community to define problems and offer solutions in many areas of social action (Bogdanović, et.al., 2021; Stojanović, et.al., 2022) and even in railway transport (Zhong, et.al., 2021). At the same time, in this way, railway companies have the opportunity to seek solutions to specific issues of their functioning and business, both outside the traditional and classical frameworks of innovation.

Despite that, Serbian railways have not tried to develop prototype solutions by applying open innovations based on the Internet of Things, thanks to which issues in specific segments of traffic will be resolved, especially when it comes to increasing safety and reducing human casualties and material damage.

Based on knowledge of open innovations and railways, an analysis of the possibility of applying open innovations based on crowdsourcing and the Internet of Things in this transport system in Serbia aims to improve safety and improve the functioning operation of railways comprehensively. At the same time, in realizing this project task, all challenges, limitations, and directions of development in this area when it comes to the railway are considered.

II. BACKGROUND

The term "open innovation" was first used by Chesbrough in 2003 in a paper (Chesbrough, 2003). According to this author, open innovation represents the use of knowledge from the company and its environment to accelerate internal innovation processes with external expertise and increase the market for external placement of existing internal innovations (Chesbrough, 2012). It is a sixth chronological innovation management model (Trott, 2017), which began in 2000 and is still ongoing. It is characterized by a combination of ideas from the internal and external environment to advance the development of new technologies.

Until about twenty years ago, innovative activities in companies were limited by the boundaries of those companies. This means these companies have implemented creative and development projects exclusively in controlled conditions, with their internal resources and knowledge and without competitiveness.

However, the development of modern technologies, especially the Internet of Things (Santoro, et al., 2018; Wang, et al., 2021), opportunities for capital inflows, an increasing number of experts in various fields of social life, as well as an increasing number of options to quality and innovative solutions come from outside the company (Cruz & Astudillo, 2020), conditioned that the previous traditional and closed innovation processes no longer give the expected results (Dhal, et.al., 2018; Radenković et al., 2020).

In such conditions, the previous model of closed innovation was faced with a shorter life expectancy for new products and rising costs of technological development. Its efficiency was constantly declining (Dodgson, et.al., 2008). Therefore, the concept of open innovation was introduced, which enabled companies to use knowledge from the immediate and widest social environment, from other companies, research organizations, educational institutions, local governments, and even directly from the citizens themselves (Santoro, et.al., 2018; Wang, et.al., 2021; Stojanović, et.al., 2020).

Accordingly, open innovations are a "distributed innovation process based on managing knowledge flows beyond the organization's boundaries" (Chesbrough & Bogers, 2014; Bogers, et.al., 2018). The critical factors for the success of open investments are clear goals, enabling cooperation, transparency, rewarding participants, finding the proper channels, and commitment (Subtil de Oliveira, et.al., 2018).

The European Commission promoted the Open Innovation 2.0 approach to synergy and integration of innovation processes, which was based on cooperation, innovation ecosystems, and joint value creation (Curley & Salmelin, 2013; Lopes, et.al., 2021). The development of information technologies and the emergence of the "Industry 4.0" paradigm have created the conditions for innovation processes today to represent the integration of knowledge in business, education, public and state administration, non-governmental sector, and individuals (Stojanović, et.al., 2021; Hizam- Hanafiah, & Soomro, 2021).

While many studies over the past two decades have addressed the challenges of the benefits of open innovation strategies or the benefits that can flow from them, few authors have analyzed the difficulties in implementing open innovations and tried to guide managers to direct such processes to better evaluate and more successfully apply open innovations. There are international research and development organizations, such as the Institute for Industrial Technology Research, that deal with a platform-based system of open innovation and its generation from idea

to commercialization to create social and economic value (Wang et al., 2021).

In the professional literature, but also in practice, the concept of open innovation is based on the crowdsourcing approach, in which the "mass of individuals" (crowd) is a source of knowledge, leading to faster, more innovative, and better solutions (Estellés-Arolas, et.al. 2012). Crowdsourcing is most often used to gather ideas at the beginning of the innovation process, which is key to successfully implementing a project (Sarić, et.al., 2022). Author Jeff Howe (Howe, 2008) defined crowdsourcing as the process by which a particular task is transferred from specialized individuals in the form of an open call to an undefined, large group of people outside the firm. If the necessary conditions are met, the community will almost always achieve better results than any employee within one company.

Open innovations are applied in various sectors and areas of social life, with the best results being obtained just when cross-sectorial cooperation is achieved. The railways and the railway industry, which are multidisciplinary and complex systems, are, thanks to this, particularly susceptible to the application of open innovations.

With the development of the Internet of Things and social networks, open innovations based on the Internet are increasingly replacing open innovations in the traditional sense, which represent organizational internal and external interaction in a limited area. Online environments offer new ideas, products, and services. Public sharing can link knowledge management and open innovation, enabling companies to reduce risk, improve speed, and open innovation platforms to reach innovative resources. This is confirmed by data collected through semi-structural interviews with eight railway transport experts (Babaei Ebrahimabadi, et.al., 2019).

In the previous two decades, Serbian railways almost did not apply the concept of open innovations as a proposal for solving specific issues of functioning and business in railway transport, and the professional literature did not deal with this topic. Meanwhile, in European and world railway companies, the application of open innovations gave original, efficient, and high-quality answers to existing problems (Dodgson, et al., 2015; Thurner & Gershman, 2014; Hanley, et al., 2022).

Thus, the international company for the production of high-speed trains "Alstom" used open innovations to solve the problem of fallen withered leaves, which caused adhesion between rails and train wheels ("Open Innovation in Railway: Example of AlstomTM | ideXlab"). Indian Railways organized an open session on future innovations in business, after which over 100,000 innovative proposals ("Improving Indian Railways with Open Innovation") arrived online. At the open call of the Eurotunnel, which connects France and Great Britain below the English Channel, 38 companies from these two countries applied with innovative proposals for improving the maintenance

of railway vehicles ("CPC and Eurotunnel Invite SMEs to Provide Railway Innovation Solutions").

Mafex, the Spanish Railway Industry Association, which brings together 90 companies, implemented the Rail Activation project with funding from the European Union's research and innovation program Horizon 2020. The main goal of this project was to create and direct railway operations and organizational mechanisms for small and medium-sized enterprises from the railway sector to take over innovation in the workplace as part of the open innovation ecosystem. Rail Activation is the first business model of its kind in the railway industry, thanks to which employees become dedicated workers through the adoption of innovations in the workplace. Within this project, research was realized, including 203 respondents from 16 European countries. (RailActivation project website <http://railactivation.eu/>)

III. METHODOLOGY

Students of the University of Belgrade, Faculty of Organizational Sciences (FON), were presented with seven characteristic situations in railway traffic in Serbia, in which safety is often endangered, with human casualties and significant material damage, which causes negative public attitude towards this traffic and business system. All this causes considerable damage to the "Infrastructure of Serbian Railways" and the railway operators in Serbia, especially in the period of substantial infrastructural and investment investments in this transport system.

Representatives of the "Infrastructure of Serbian Railways" presented to FON students the following characteristic situations on Serbian railways:

1. Traffic safety at road crossings;
2. Accidents from electric shock from the catenary above the railway;
3. Creating conditions for easier use of the railway for persons with reduced mobility and disability;
4. Destruction of the protective fence along the railway;
5. Noise from railway traffic;
6. Theft of parts of railway infrastructure and equipment;
7. Accidents on the open track.

FON students were divided into seven groups, with between three and six participants. After getting acquainted with the topics, groups of students could request additional information for a better approach to solving problems.

Each group proposed a prototype solution for one of the seven presented topics based on information, analysis, and research, based on crowdsourcing, open innovations, and the Internet of Things, to reduce the number of such situations and their consequences on railway traffic. In cooperation with FON students, the authors of this paper conducted this research for three months in 2022.

IV. RESEARCH AND OBJECTIVES

Within the research conducted in cooperation with FON students, with the help of experts from the "Infrastructure of Serbian Railways," seven distinct areas in railway traffic were defined, which frequently occur, resulting in human casualties, endangering traffic safety, tremendous material damage and deteriorating public attitudes towards this traffic system.

The paper aimed to find and propose prototype solutions on crowdsourcing principles and based on information, analysis, and research of the mentioned situations, which will reduce the number and consequences of such events on Serbian railways. The prototype solutions result from crowdsourcing and the application of open innovations based on information technologies, mainly on technologies of the Internet of Things. The following seven areas and characteristic situations in railway transport have been defined, with significant detrimental consequences for human lives and property:

Traffic safety at road crossings

Description of the situation: When crossing the railway, drivers of road vehicles do not respect the road signalization (Andreja's cross, STOP sign), do not stop in front of road crossings, cross the railway carelessly, and irresponsibly, slip under lowered ramps and break them. All this leads to accidents at road crossings, for which, according to official statistics, drivers of road vehicles are responsible in 95% of cases and in which there are fatalities.

Terms of reference: Proposed open innovation that will increase the attention of road vehicle drivers, improve compliance with traffic signals, increase traffic safety and reduce the number of accidents at road crossings.

Accidents from electric shock from the overhead contact line

Situation description: Young people in train stations climb on freight cars for selfies or fun. While climbing, they enter the circuit around the contact network, where the voltage is 25 thousand volts, and they are killed due to an electric shock. On average, five young people die each year in this way.

Project task: Proposal of open innovation that warns young people not to climb on wagons, approach the circuit from the catenary, and threaten the dangers of the catenary above the railway. That proposal reduces the number of such cases and the number of human victims.

Creating conditions for easier use of the railway by persons with reduced mobility and disabilities

Description of the situation: In many railway stations in Serbia, persons with reduced mobility and disability do not have adequate conditions for the use of these facilities. This is especially true of the large number of stations in Serbia built several decades ago when social awareness

and responsibility were not at a high level. This applies to people with reduced mobility, blind and partially sighted, and deaf and hard of hearing people who have difficulty using railway services and facilities.

Project task: Proposal of open innovations to enable disabled people to make more accessible and safer use of railway services and facilities.

Destruction of the protective fence along the track

Description of the situation: A protective fence has been installed along the railway along the first Serbian high-speed railway Belgrade - Novi Sad, and on a small number of other railways in Serbia. Citizens are destroying this fence along the railway to cross the railway in illegal places, thus endangering their lives and traffic safety.

Project task: Open innovations based on which citizens will be warned not to do so, and damage to the protective fence along the railway will be registered and detected the fastest.

Noise from railway traffic

Description of the situation: More and more often, the railways are addressed by citizens from the settlements near the railway, with remarks that the railway is making too much noise and asking for the installation of sound fences along the railway.

Project task: Regular monitoring of noise along the railway through open innovations to a timely response.

Theft of parts of railway infrastructure and equipment

Description of the situation: Thefts of parts of the railway infrastructure and equipment are daily, and the damage that the railway suffers because of that is measured at the annual level of tens of millions of dinars. In addition, in this way, the safety of railway traffic is endangered, transport is interrupted on certain sections, and it happens that those people are killed during the theft.

Project task: Open innovations that will protect railway infrastructure and equipment, with the aim of reducing the number of such cases and material damage caused to railways.

Accidents on the open track

Situation description: People are injured while moving on the railway so that a train hits them. Some suffer because of their carelessness (phone calls or earphones) because they come to the railway zone and the train runs over them. Other people commit suicide. In none of these situations can a train driver avoid an accident.

Project task: Proposed open innovations, which will warn carelessness people that they are moving in the railway zone, that a train is coming and that they are in danger.

V. RESULTS

Students who participated in the research and application of crowdsourcing should have proposed a prototype based on open innovations as a solution for specific situations in railway traffic and did not say that this transport system is a great challenge in this area. In the past decades, there were no significant investments in railway infrastructure and vehicles and almost no investments in maintenance, which is why this type of transport was slow and of poor quality.

Although the investment process in the railways worth about five billion euros has begun in the past few years and the first Serbian high-speed railway at 200 km / h has been built, this attitude of researchers shows that more time is needed for this mode of transport to become attractive, challenging and promising for researchers and students, not only when it comes to the application of open technologies, but also modern technical and technological solutions in the modernization of railways and trains.

The students were most interested in creating a prototype based on open innovations, which would create conditions for people with reduced mobility or disabilities to use the railway more easily. In this way, they showed a high level of social awareness and responsibility for solving the problems of people with special needs. In the coming period, this can direct future research on the principles of open innovation in this area, but at the same time initiate the railway to address the issue of people with special needs much more actively on the principles of open innovation.

On the other hand, none of the student groups showed interest in finding a prototype solution for accidents that occur on the railway from high voltage electric shocks from the contact network above the railway. The participants in the research did not sufficiently or at all recognize the danger posed by the contact network above the railway with a voltage of 25 thousand volts, which kills an average of five young people a year, primarily due to selfies or climbing wagons. Since the participants in the research were also young, the lack of interest in this problem may mean that students were not aware of the potential dangers of electric shock in this situation, but also that the railway did not get to know the young people well enough by climbing on the wagon and approaching the catenary above the track, they can get hurt. Both reasons in the coming period should direct further activities of the railway to solve this problem, both by finding a prototype of open innovations based on the Internet of Things and by applying modern technical and technological solutions.

Although all groups during the research had the opportunity to turn for additional information and explanations for each of the areas and characteristic situations in railway traffic, the research group used this opportunity to propose a prototype solution for the protection of railway parts and theft equipment, the aim of which was to reduce the number of such thefts and material damage to the railway on that basis.

The questions that this research group of students asked to find the best prototype for the protection of railway parts and equipment from the theft were:

- a. What equipment needs to be protected?
- b. How has the problem of equipment theft been solved so far?
- c. In which places do thefts most often occur?
- d. In what time interval do theft of equipment most often happen?

Students who participated in this quarterly research on the above issues and areas of railway safety proposed a prototype of open innovations based on crowdsourcing, which answered the project task and offered solutions to specific situations on the railway. In addition, during the research, students developed solutions based on project management and proposed marketing plans for product and service development.

During the preparation of the open innovation prototype, the researchers faced the limitations and challenges posed by a complex technical-technological system such as the railway. Widespread (3,500 km of railways in Serbia), a large number of executors in the organization and functioning of railway traffic, the impact of other traffic participants and service users on railway safety, complexity and interdependence of infrastructure and transport capacities, significant funds needed for investment and maintenance of railways, etc.

These are just some of the limitations that students encountered when researching and finding open innovations as a proposal for solving specific issues of railway safety.

At the same time, when finding open innovations in the form of prototypes, students, in addition to these limitations, had in mind the possibilities for their practical application, including technical-technological and financial aspects. With the proposed open innovations, the participants in the research offered solutions based on the Internet of Things, which can increase safety and reduce harmful consequences in specific segments of the functioning of railway traffic.

VI. CONCLUSION

Solving problems in railway traffic by applying open innovations represents a complete business novelty in the functioning of this transport system.

Until now, railway companies have not practiced trying to solve specific problems in their functioning with open innovations. The classical approach to solving the mentioned situations in railway traffic is costly and technically and technologically complex, so its application is limited and more difficult. Therefore, there is a justified business and functional need for the railway system to solve certain characteristic situations for traffic safety by applying open innovations, which can be much easier to use, more

straightforward, cheaper, and more rational while achieving the desired effects.

In this research and work, for the first time, open innovations and prototype proposals based on them are proposed as a new solution to essential issues of railway traffic safety. The first such attempt after the research is a significant business and technical-technological innovation in approaching the most complex topics of railway safety, even when the proposed prototype solutions apply only to the local level and specific segments of the global problem.

The realized research confirmed that the application of open innovations based on crowdsourcing and information technologies, mainly on technologies of the Internet of Things, can improve traffic safety in specific segments of railway transport.

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