Traffic & Transportation

Assessing the Effects of Implementing Railway Technological Innovations on the Competencies of Logistics Specialists

Gintautas BUREIKA[1], Kristina VAIČIŪTĖ[2], Valerii SAMSONKIN[3]

Original Scientific Paper
Submitted: 22 Mar 2025
Accepted: 8 Sep 2025
Published: 29 Jan 2026

[1] gintautas.bureika@vilniustech.lt, Department of Mobile Machinery and Railway Transport, Faculty of Transport Engineering, Vilnius Gediminas Technical University, Vilnius, Lithuania
[2] Corresponding author, kristina.vaiciute@vilniustech.lt, Department of Logistics and Transport Management, Faculty of Transport Engineering, Vilnius Gediminas Technical University, Vilnius, Lithuania
[3] samsonkin1520mm@gmail.com, State University of Infrastructure and Technologies, Kyiv, Ukraine

Publisher:
Faculty of Transport and Traffic Sciences, University of Zagreb

ABSTRACT
The level of technological innovation and the efficiency of transport logistics in enterprises principally depend on the resources that are used. The authors aim to develop a new approach to assess the interface between railway innovation implementation and the competencies of logistics specialists. The application of advanced technologies, such as digitisation and automation, substantially improves key performance indicators while simultaneously lowering operational costs for railway undertakings. There are notable advancements in technology within railway transport, with a particular emphasis on digitalisation. Analysis and research to determine specific engineering competencies of logistics specialists are highly anticipated and needed. This research focuses on the analysis and assessment of the interconnection between technological innovations in railway transport and the engineering competencies of logistics specialists. An analytic hierarchy process (AHP) method is used to assess the impact of technological innovations on the engineering competencies of logistics specialists, aiming to establish the presumed link between social psychological and technological factors. A new approach for assessing the competencies of logistics specialists in the railway sector has been developed. It is proven that the implementation of technological innovations within railway companies serves as the decisive factor driving the improvement of engineering competencies for logistics specialists.

KEYWORDS
railway transport; railway undertaking; technological innovations; logistic specialist; engineering competences; AHP.

1. INTRODUCTION

Railway transport companies operate in constantly changing and extremely competitive market conditions. In order to remain competitive in the railway transport market, companies must respond in a timely manner not only to economic and social circumstances but also to technological changes. Worldwide researchers examine new technologies, their challenges and opportunities for the railway system to understand possible futures of the railway systems, allowing them to prepare ahead of time to exploit its competitive strengths and possible technological developments. Successful innovations should help the European transport industry in maintaining its global competitiveness. Railway companies constantly monitor the level of their infrastructure capacity, the condition of assets, locomotive driver assistance systems, energy consumption and environmental pollution. As transport technologies and technical infrastructure capacities in railway companies improve, it is necessary to constantly improve the engineering competencies of competent logistics specialists working in the field of railway transport. The inability to systematically link technological progress in railway transport and the engineering competencies of logistics specialists may lead to the decline of the technological infrastructure of companies and the necessary pace of rolling stock renewal and/or acquisition. Research hypothesis: the level of engineering competencies of logistics specialists ensures targeted and timely development, selection and productive use of the technological infrastructure of railway transport companies, and vice versa. Thus, it is assumed that the implementation of innovations in railway companies leads to a need for higher-level engineering competencies. The scope of this study is the indefinite impact of the intensity of the implementation of railway technological innovations on the engineering competencies of logistics specialists. It is relevant to substantiate the need for updating engineering competencies and the readiness of specialists at all levels of the company to implement and master technological innovations. Due to the too low level of engineering competencies, the technological infrastructure of railway companies is used unproductively. At the same time, advanced economic and organisational measures are not rationally applied. Technological innovations reduce the technological gap between consumers (clients) of different levels and significantly contribute to the sustainable development of the EU market. Innovations create an appropriate economic environment in railway companies and ensure the appropriate dissemination of information about the services offered. The authors aim to develop a new approach for assessing the process of competencies of logistics specialists in the railway, taking into account the interconnection between the technological and social issues.

2. LITERATURE REVIEW

In the scientific literature, technological development in the activities of a railway transport company is presented as innovations in technologies used during cooperation. These innovations are associated with the ability to obtain the necessary information while ensuring the quality of the service provided. Increasing technological development enhances the necessary skills of a logistics specialist to adapt to technological changes. When transferring large amounts of data, railway companies must ensure the effective use of technology, which depends on the evolving competence of logistics specialists.

2.1 Development of technological innovations in transportation

The concepts of technological development and innovation activities are defined in accordance with the guidelines of the Organisation for Economic Co-operation and Development (OECD) publication Oslo Manual [1]. The OECD distinguishes four main types of technological development: product, process, organisational and marketing. The research on technological development carried out by Loschky [2] provides an overview of the concept of the high-tech sector based on technological impact on other production sectors and identifies the most important advanced technologies. The analysis of the works pertaining to technological development (innovations) shows that there is no uniform position when it comes to defining technological development. Arifin & Frmanzah [3] and Hagiu & Altman [4] look at the technological development of transportation companies from a socio-economic perspective. The findings of their research confirm that the application of advanced technologies in businesses significantly improves a company's performance indicators in the following aspects: reducing operating costs, increasing production performance, promoting responsibility, minimising carbon dioxide CO_2 and its impact on the environment, increasing productivity and extending the company's life cycle. Heitmann et al. [5] define technological development as equipment and devices designed to create and manage the man-made civilised environment. According to Królczyk et al. [6], Korucuk & Aytekin [37], technological development is linked to increased consumer demands, business development and opportunities for cooperation with other transport and logistics companies. The implementation of technological innovations promotes the creation and implementation of information and technological advancements [7]. The implementation of technological innovations in the railway sector encompasses the areas of science, technological progress and the business market (ERRAC 2024). There is an interconnection between the implementation of technological innovations and the activities of a railway undertaking for which there is no objective explanation. This interconnection is based on technological measures between the cooperating entities, as well as on employee competencies, and innovations introduced in diverse operations within a transport company. The description of this relationship does not emphasise separate activities, and the interconnection between the existing activities within the transport company and technological development is presented as a whole. The 2015 OECD Research Report on the State of Science, Technology and Industry no longer uses the term “high technology”. The report on the state of the technology market points out that investment in the development of technological innovations is rising, particularly those innovations that bring transformative changes in a particular area of activity. The role of highly qualified specialists in the global value supply chain is emphasised, and the need to invest in human resources and employee competencies becomes even more relevant [8]. The EU’s economic policy documents clearly define the importance of the technology sector and its impact on traditional industries. These studies and documents demonstrate a change in the traditional understanding of the technology sector and give a new impetus to the development of the EU’s transportation industry. In addition, the ongoing process is promoting the search for new theoretical and methodological research directions aimed at effective management of advanced technologies and technology transfer in the context of open innovation. Researchers Hirsch-Kreisen [9], Walwei [10] Nayan et al. [11] state that the process of globalisation and technological advances has laid the foundations for the emergence of a new global economy based on knowledge and information. Scientists Stevanović & Stevanovic [12] and Attah et al. [38] concluded that the implementation of technological innovations was necessary for the exchange of information within undertakings in the context of cooperation between railway undertakings. Information is provided quickly and efficiently. Information transfer via technological means, efficient exchange between companies offering services in different modes of transport and good management of technological information are obligatory.

Investing in R&D activities provides transport companies with strategic and organisational flexibility, encouraging companies to form strategic cooperation networks with other companies and research institutes and to increase the value of the service. These investments also increase opportunities to absorb knowledge gained from participants in collaborative networks and use it to enhance companies’ productivity. According to Lovelace et al. [13], the implementation of technological innovations by transport companies is linked to transport companies’ ability to obtain information with the help of devices, which thus preserves natural resources and ensures the quality of services. Researchers Bazaras & Palšaitis [14] and Vasilis Vasiliauskas et al. [15] claim that the importance of technologies in transport undertakings is associated with costs, delivery times, service prices and the speed of transportation. In their opinion, the technical level of transportation affects the efficiency of transport companies. According to Cleophas et al. [16], Zhao et al. [17] and Stone et al. [18], the development of technological innovations can be defined as a tool for minimising pollution and implementing innovative technologies for the transportation process. The aforementioned researchers present the implementation of technological innovations as an improvement to the transportation system that enables better and more efficient use of the present technological infrastructure. These systems increase the productivity of the transport sector, protect human health and life, save time, money and energy. It is worth noting that these researchers did not analyse employee competencies. Scientists Bolodurina & Mishurova [19], Rosi & Obrecht [40] argue that technological development should be linked to the availability and usage of information technologies and telecommunications, as well as the implementation of the latest technological innovations. Kostrzewski et al. [20] draw attention to the fact that the economic efficiency of operations in transport undertakings is obtained by implementing different groups of innovative technologies and systems. Researchers Nold & Corman [41] collected and organised inputs to identify and discuss technologies and innovations, and assessed their potential for the development and improvement of the complete railway system.

Researchers Kaveckė & Paužuolienė [21] conclude that the relationship between technological development and a company’s financial results, for instance, like profitability, is indirect and complex. To analyse the technological development of railway transport undertakings in more detail, the concept for implementing technological innovations is formulated. The implementation of technological innovations in transport undertakings is the updating and renewal process of the new information products and technical means (communications, signalling, automation and technical diagnostics systems, engineering networks, specially equipped areas, rolling stock), as well as the introduction and adoption of the new rolling stock management systems and innovative technologies in transportation processes.

The factors that promote technological innovations and enhance operational efficiency are identified and presented in *Table 1*. These factors are used for establishing a model for the connection between railway transport companies’ technological innovations and the engineering competencies of logistics specialists.

Table 1 – Factors influencing the implementation of railway technological innovations (compiled by the authors)

Directions for implementing technological innovations	**Factors increasing operational efficiency in railway transport companies**
Improvement of logistics cooperation and technological compatibility between railway transport companies	Updated technical bases to effectively manage service organisation and technological compatibility with other companies and modes of transport.
Improvement of advanced railway transport technologies	Real-time monitoring of the rolling stock via innovative technologies, driver assistance and integration of the rolling stock control system.
Improvement of engineering networks (communication means)	Managing innovative technologies, cooperating entities exchange and process data.
Enhancing the technical levels of technological equipment	The impact of the updated technical bases on the compatibility with other companies and modes of transport.
Updating and installing the new IT systems	The impact of the development of coordinated information systems (designed for cooperation) on the competencies of logistics specialists and service productivity (change in the cost of 1 tkm of turnover), and technological compatibility with other modes of transport.
Automatic cargo identification systems	Digitalisation of loading operations combines activities into systems that speed up transportation and loading processes and reduce the amount of manual labour.
Management system for driver assistance and traction units	The updated systems connect the operations of train traffic control and driver assistance systems, as well as increasing railway traffic safety and line capacity.
Railway infrastructure systems (automation, signalling, traffic control systems and diagnostics devices for track quality condition)	Digital infrastructure management systems ensure prompt and reliable train traffic control.

As presented in *Table 1*, the adoption of technological innovations is linked to engineering-technological means necessary to conduct operations in a railway transport company. This includes the renewal of the rolling stock, the implementation of a traction rolling stock information system and the improvement of the railway traffic control system. This ensures communication between departments or companies. The development of these objects is associated with qualitative and substantially higher levels of services offered by railway transport undertakings. These circumstances enable undertakings to remain competitive in the transportation market. The adoption of technological innovations is dependent upon the actions of technology professionals, their knowledge (competencies) and capacity to analyse and assess complex situations independently. The introduction of technological innovations is also linked to the emergence of new products and the capacity to integrate innovative technological products into old equipment, allowing them to operate as if they were new.

2.2 Development of competencies for logistics specialists in railway transportation

The accelerated progress of technologies and the ongoing acquisition of new knowledge encourage logistics specialists to constantly seek professional development opportunities and deepen their knowledge. The knowledge, skills and abilities of a specialist act as an important resource for sustaining competitiveness amidst fast-paced changes in technologies. According to research findings by Taguma et al. [22] and Berger & Frey [23], Wahab et al. [42], employees willing to maintain their competitive edge in the labour market must constantly obtain new technological skills. This requires employee flexibility, a positive attitude towards life-long learning and the enhancement of competencies. Employee competency enhancement is centred around the development, maintenance and improvement of creative, entrepreneurial and technical skills. Logistics specialists are allowed to acquire new professional competencies and adapt to new technologies. According to Becker [24], the competencies of logistics specialists are classified into two categories: professional (speciality) competence that encompasses all knowledge and preparations required for specific professional tasks and management (operational) competence characterised by the ability to operate in an organised manner, as well as to partially or fully integrate other competencies.

In her analysis on the competencies of a transport manager, Ms. Ledauskaitė [25] claims that a logistics specialist is a person with education in this field and is equipped with competencies enabling to connect all logistics operations, optimise logistics costs, plan, manage and control information and material flows, processes in terms of space and time from the primary source to the end user. The competence of a logistics specialist is closely connected to professional activities; thus, general abilities are integrated with subjectspecific and methodological competencies depending on the profession being acquired. It is only at this stage that professional competencies emerge. In other words, depending on the context, the competencies of a logistics specialist are intertwined. According to Geistmann [26], Susanto et al. [43] a professional competence comprises content competences and methodological competences of specific activities. Dulewicz [27] determined that 70 per cent of competencies are universally applicable to all organisations, while 30 per cent are tailored to specific ones. Consequently, it is very important to select an appropriate model for competence assessment, although the researcher did not provide the model itself. Laužackas [28] states that the fundamentals of competence lie in the accumulated professional experience and knowledge, as well as sufficient qualification. Martinkienė [29], Geistmann [26] emphasise that a qualified logistics specialist has certain functional abilities, i.e. professional competencies. Thus, in this case, a competent logistics specialist has the skills and abilities in his/her line of work – a logistics competence. As noted by Bazaras & Palšaitis [14], Chlivickas et al. [30], logistics service organisations and users of this service place a considerable emphasis on the following characteristics of logistics specialists: professionalism, skills, efficiency, flexibility, reliability, attitude, behaviour, reputation and honesty. Juodeikaitė & Fominienė [31] discovered that fluctuations in the market necessitate transport companies to constantly reevaluate the competencies of their employees and adapt to entrepreneurial changes. According to the research, the ongoing changes in the labour market introduce new challenges and subsequently suggest that, although significant, the competencies based solely on professional skills are insufficient. It is also important to develop personal, social and intercultural competences. A considerable number of researchers highlight the fact that logistics specialists must update their knowledge, skills or acquire new ones to successfully navigate in a professional world characterised by ongoing technological advancements. In their research, Chowdhury & Murzi [32], Juodeikaitė & Fominienė [31] and Savanevičienė et al. [33] found that the successful performance of employees depends on their capacity to adapt to a rapidly changing environment. Thus, it is imperative to focus on current requirements aimed at competencies, as well as to anticipate the future ones. The competencies of railway transport logistics specialists are regarded as their ability to influence teamwork both directly and indirectly. The competencies of logistics specialists are divided into groups. In line with the professional standard established in 2015 and revised in 2021, a logistics manager (qualification level VII) must demonstrate a range of professional competencies. These include the ability to evaluate client orders, supervise the order fulfilment process, manage inventory, organise the packaging and shipping processes of logistics products, and plan, organise and control material flows in the organisation. A freight forwarder (qualification level IV, i.e. completion of master studies) is required to demonstrate the following competencies: to present the offered services of transport and logistics in native and foreign languages; proficiency in utilising office equipment; the capacity to set criteria for vehicle and cargo selection; the ability to determine the most optimal routes for cargo transportation; the application of geographic information systems; the application of transport tracking programs; the application of logistics information systems; the capacity to apply modern general information systems. The competencies of a logistics specialist are connected to their ability to execute specific tasks in transport and logistics. Changes in the railway transport companies market show that the development of personal, social and managerial competencies of employees working in the company is necessary. Nuthal [37] presented a classic competency formation scheme, which emphasises the change in competencies. The dynamic nature of the rail industry necessitates a timely assessment of the required and lacking competencies of logistics specialists. The revised competencies of a specialist working in railway transport are presented in *Figure 1.* Employees who have developed technological competencies are capable of operating automated equipment utilised in manufacturing. Knowles-Cutler & Lewis [34] and Dittrich [35] determined that the necessity for technological skills is minimised when innovative solutions are being implemented. This is explained by the highly influential AI and its development, where various technical tasks are performed without human intervention. According to Tsekeris [36], who focuses on workplace robotisation and automation, it is essential for employees to constantly update their technical (technological) and digital skills.

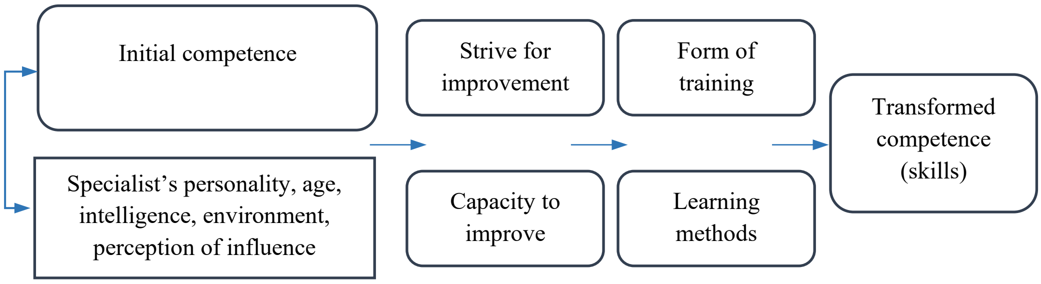

Figure 1 – Flowchart of competence formation (compiled on Nuthal [37])

The data in *Figure 1* show that improvement possibilities and the efficiency of qualification enhancement depend on general personal characteristics.

The introduction of new information systems within railway undertakings facilitates an accelerated transfer of information flows through various technologies. The traditional skill set of logistics specialists is insufficient when it comes to handling big data and managing information. The utilisation of updated innovative technologies in managing information rationalises the transportation process and improves operational performance in railway undertakings. Enhancing the engineering competencies of logistics specialists ensures faster adoption of innovative technologies and their productive application in the company's operations. It makes a great impact on general efficiency.

3. RESEARCH METHODOLOGY CONCERNING THE EFFECTS OF IMPLEMENTING INNOVATIONS ON COMPETENCIES

The multi-criteria decision-making methods are applied to assess the effects of implementing technological innovations in railway undertakings. Compared to other multi-criteria decision-making methods, the analytic hierarchy process (AHP) method is advantageous due to its flexibility, conversion of qualitative indicators to quantitative ones, its convenience for decision makers, as well as the possibility to evaluate the consistency of expert opinions [44]. The AHP method is based on criteria and a pair-wise comparative matrix. Methods for determining the weights in multicriteria assessment are based on expert judgements, i.e. expert opinion. These opinions and judgments are guided by the knowledge and experience in railway transportation. Experts are chosen by several selection methods, including the assessments of their competencies based on data (education and professional experience) and continuous evaluation of their competence (professional experience in the researched area and continuous professional development). The advantage of the AHP method over other multi-criteria decision-making methods is its flexibility, convenience for decision-makers, and the ability to check the consistency level of expert opinions. AHP model captures subjective expert knowledge about innovation and competence; structures it into a rational, transparent framework. Furthermore, the AHP algorithm supports interdisciplinary decision-making by integrating technical, behavioural and strategic dimensions.

Experts compare all of the criteria under assessment whilst assigning indicators R_i and R ($i; j = 1,..., n$), (n – number of indicators).

The comparative result is the inversely symmetric matrix [45]:

$$\boldsymbol{P} = \|p_{ij}\| \; (i, j = 1, \ldots, n). \tag{1}$$

The components p_{ij} of matrix $\boldsymbol{P}$ are treated as weight value ratios for indicators R_i and R_j, when

$$p_{ij} = {}^{1}/_{p_{ji}}. \tag{2}$$

The normalised geometric mean method is utilised to determine the weight ω_i of the criteria j in the process of calculating priorities [46]:

$$\omega_i = \frac{\sqrt[m]{\prod_{j=1}^{m} P_{ij}}}{\sum_{i=1}^{m} \sqrt[m]{\prod_{j=1}^{m} P_{ij}}} \tag{3}$$

Prior to the ranking process, the consistency of the completed matrices is determined. The consistency index is used for this purpose *CI* [44]:

$$CI = \frac{\lambda_{\max} - m}{m - 1} \tag{4}$$

where: *CI* – consistency index; m – number of criteria; $\lambda_{\max}$ – maximum eigenvalue of the matrix ***P*** (comparison of expert opinions). The greatest value of the comparison matrix for expert opinions:

$$\lambda_{\max} = \frac{1}{m} \cdot \sum_{i=1}^{m} \frac{\sum_{j=1}^{m} P_{ij}\,\omega_j}{\omega_i} \tag{5}$$

where: $\lambda_{\max}$ – maximum eigenvalue; ***P*** – comparative matrix for expert opinions, m – number of criteria; ω_j – alternative j-th weight. Should the comparative matrix ***P*** for expert opinions be ideally coordinated, then $\lambda = m$. The consistency index is compared to the random index, and the consistency ratio is obtained:

$$CR = \frac{CI}{RI} \tag{6}$$

where: *CR* – consistency ratio; *RI* – random index, dependent on the matrix sequence *n* and is presented in *Table 2*.

The AHP method demonstrates the agreement between the evaluations provided by each expert. According to Saaty [44], if the consistency ratio *CR* is less than 0.1, the matrix is considered to be in agreement. In the process of evaluating a specific criterion, the average is multiplied by the weight and a generalised estimate for the selection criterion is obtained. The criteria that accumulate the highest total score are assigned the 1st rank.

Table 2 – Random value of index RI (Saaty [44])

Matrix sequence *n*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Index RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

In order to obtain more accurate reliability of these results, they are compared and correlated with the results obtained by different methods. Therefore, expert rating data evaluation and polynomial methods were chosen. Polynomial choice models are used when there are three or more options to choose from. Regression analysis is used as a tool to examine the relationship between two variables [47]. The study is carried out in 4 stages:

1) criteria are determined;
2) a multi-criteria method is selected;
3) determining the significance of the selected criteria;
4) results.

Multi-criteria analysis methods are used to predict decisions and provide an opportunity to classify indicators according to expert opinion [48]. The perception and assessment of criteria by different experts differ, which means that the weights of the obtained criteria and their priorities may vary [49]. The confidence interval for the mean of a normal distribution indicates the quality of the measurement. A confidence level of 0.9 means that when a specific confidence interval is constructed many times, the parameter falls within 90% of all intervals. The longer the interval, the higher the confidence level.

The average of the rank sums is calculated:

$$\sum_{i=1}^{n} R_{ij} - \frac{1}{2}n(m+1), \tag{7}$$

where: R_{ij} – a rank of R; j – the sequence number of the alternative; i – the sequence number of the expert; n – the number of experts; m – the number of benchmarks.

A concordance coefficient W is defined:

$$W = \frac{12S}{n^2 m(m^2-1)} = \frac{12S}{n^2(m^3-m)}; \tag{8}$$

where: S – the sum of the squares of the squares of deviations from the arithmetic mean.

A Pearson criterion χ^2 is calculated:

$$\chi^2 = n(m-1)W = \frac{12S}{nm(m+1)}. \tag{9}$$

The minimum value of the concordance coefficient W_{min} is calculated:

$$W_{\min} = \frac{\chi^2_{v,\alpha}}{n(m-1)}, \tag{10}$$

and

$$S_{\max} = \frac{n^2 m(m^2-1)}{12}, \tag{11}$$

$$\bar{R} = \frac{1}{2} n(m+1). \tag{12}$$

The lowest value of the concordance coefficient W_{min} is calculated by *Equation (10)*. If the variance S is a real sum of squares calculated according to *Equation (7)*, then the concordance coefficient by *Equation (8)*, in the absence of related ranks, is defined by the ratio of the resulting S to the corresponding maximum S_{max} by *Equation (11)*. In light of the experts' evaluation indicators (12), the consistency of their opinions is determined by calculating the concordance coefficient of the Kendall ranks. Threshold value for the concordance coefficient, where expert assessments are considered coordinated and the significance of the concordance coefficient is determined using the Pearson criterion χ^2 by *Equation (9)*.

In order to ensure the quality and reliability of the expert review, it is necessary to form a group that should consist of more than 2 experts and no more than 10 experts [50, 51].

4. EVALUATION OF THE EFFECTS OF INTRODUCING INNOVATION ON THE COMPETENCIES OF LOGISTICS SPECIALISTS

The research into the influence of introducing technological innovations on the competencies of logistics specialists in railway undertakings unveils distinct directions of technological development and engineering competencies of logistics specialists.

A questionnaire survey method was applied in assessing both the engineering competencies and directions of introducing technological innovations. Eight experts were selected according to obligatory characteristics: master's degree, type of supervisory position and at least 5–10 years of professional experience in the transport sector. The qualification list of the selected experts is provided in *Table 3*.

All experts were presented with questionnaires consisting of the following groups of questions:

1) Personal information (occupation, education and professional experience).
2) Pair-wise assessment for directions of introducing technological innovations.
3) Pair-wise assessment of engineering competencies of transport logistics specialists.

Table 3 – Characteristics of experts (compiled by the author)

Expert	Education	Job responsibilities	Work experience	Professional experience
E1	Master	Manager	7	5
E2	Master	Manager	8	8
E3	Master (2 qualifications)	Deputy manager	18	10
E4	Master	Manager	7	5
E5	Master	Manager	8	6
E6	Master	Manager	8	7
E7	Master	Deputy manager	15	10
E8	Master	Manager	8	7

The selected directions for introducing technological innovations are presented in *Table 4*. The consistency ratio *CR* and the maximum eigenvalue of the matrix λ are in line with necessary conditions: $CR < 0.1$, where λ_{max} is close to the value 9. Thus, expert opinions are in agreement.

According to the significance data on the directions for implementing technological innovations summarised in *Table 4*, the greatest significance is assigned to the following directions: compatibility of technologies for logistics cooperation in railway transport (0.225) and improvement of intelligent transport systems (0.210). A linear function between technological innovations and specialist competencies is determined by the links between these two criteria.

Table 4 – Consistency of expert opinions and directions for implementing technological innovations in railway transport companies (compiled by the author)

Consistency of expert opinions	**Overall**		
Consistency ratio *CR*	0.0214		
Maximum eigenvalue λ_{max}	9.249		
Competitiveness strategy for technological innovations			
Directions	**Geometric mean**	**Normalised eigenvector**	**Rank**
Compatibility of technologies for logistics cooperation in railway transport	0.220	0.225	1
Improvement of intelligent transport systems	0.205	0.210	2
Improvement of engineering networks (communication means)	0.191	0.196	3
Enhancing the technical levels of technological equipment	0.105	0.107	4
Updating and installing the new IT systems	0.085	0.087	5
Automatic cargo identification systems	0.074	0.076	6
Management system for traction rolling stocks	0.042	0.044	7
Railway infrastructure systems	0.028	0.028	8
European railway traffic management systems/European train control system (ERTMS/ ETCS)	0.027	0.027	9

The interconnection between implementing technological innovations and the competencies of logistics specialists in railway transport undertakings is provided in *Figure 2*.

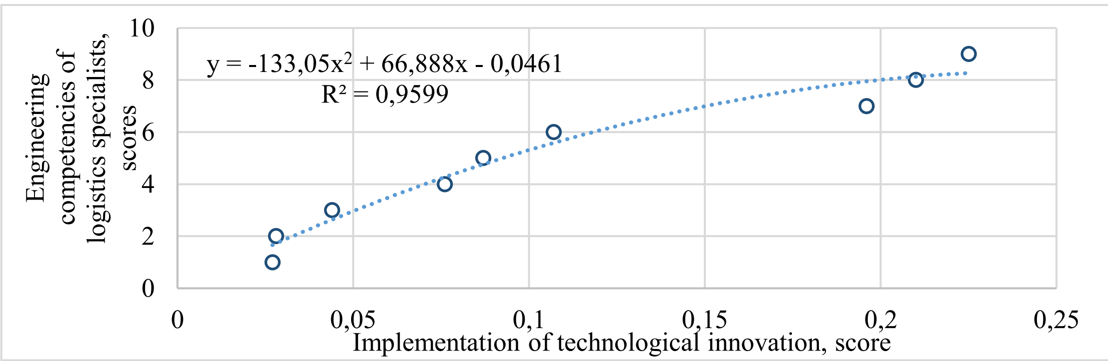

Figure 2 – Interconnection between the implementing technological innovations in the railway transport company and the logistics specialists' competencies (compiled by the authors)

The criterion estimates obtained from *Figure 2* and the 2nd degree equation indicate that a fourfold increase in the intensity of implementing technological innovations in railway undertakings results in an eightfold increase in the demand for enhancing the competencies of logistics specialists. The analysis uses polynomial curve fitting. The closer R^2 is to 1, the stronger the correlation between the variables under study. In this case, correlation is strong. The engineering competencies selected by the authors, especially for more detailed research, are presented in *Table 5*.

According to the data presented in *Table 5*, it was determined that the highest significance is assigned to the following competencies: digitalisation of rolling stock management systems (0.170) and management of technical maintenance and repair processes (0.161).

The linear function between technological innovations and engineering competencies determines the link between both criteria.

Table 5 – Ranked engineering competencies of logistics specialists

Criterion	**Final significance**	**Rank**
Engineering competence group, Levels VI–VII		
Digitalisation of rolling stock management systems	0.170	1
Management of technical maintenance and repair processes	0.161	2
Familiarity with the necessary procedures to follow in case of rail vehicle failures	0.153	3
Maintaining technological infrastructure in a transport organisation	0.152	4
Providing consultations on technological queries	0.138	5
Assessing completion of tasks and the overall technical accuracy of achievements	0.079	6
Design of different assemblies, systems and compounds	0.077	7
Assessment and preparation of engineering documentation	0.070	8

The interconnection between introducing technological innovations in railway undertakings (x) and the demand for engineering competencies of logistics specialists (y) is illustrated in *Figure 3*.

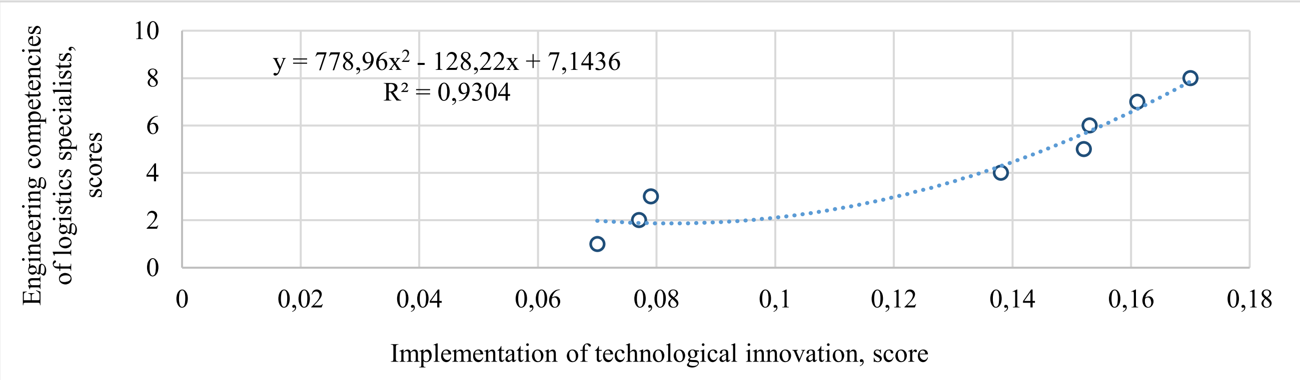

Figure 3 – Interconnection between the implementation of technological innovations in the railway transport company and the improvement of logistics specialists' competencies (compiled by the authors)

The criterion estimates obtained from *Figure 3* and the 2nd degree equations show that increased levels of technological innovations in railway undertakings have subsequently enhanced demands for engineering competencies among logistics specialists. In this case, there is a strong correlation, R^2=0.9304.

Experts assessed the effects of elevating the technical level of devices pertaining to implementing technological innovations on engineering competencies:

I_1 – Providing consultations on technological queries;
I_2 – Design of different assemblies, systems and compounds;
I_3 – Assessing completion of tasks and overall technical accuracy of achievements;
I_4 – Assessment and preparation of engineering documentation;
I_5 – Digitalisation of rolling stock management systems;
I_6 – Management of technical maintenance and repair processes;
I_7 – Familiarity with necessary procedures to follow in case of rail vehicle failures;
I_8 – Maintaining technological infrastructure in transport organisation.

In the analysis of the pair-wise comparison matrices derived from expert responses pertaining to the effects of implementing technological innovation (i.e. increasing technical levels of technological devices) on engineering competencies of logistics specialists, the consistency ratio (*CR*) was determined. The calculation method is as follows:

$$CR = \frac{C.I.}{RI} = \frac{\frac{\lambda_{\max} - m}{m-1}}{1{,}41} = \frac{\frac{8.361-8}{7}}{1.41} = 0.036 \quad (13)$$

where: *RI* – random index; *m* – number of criteria; $\lambda_{\max}$ – maximum eigenvalue of the matrix ***P*** (comparison of expert opinions). If the comparative matrix ***P*** for expert opinions is coordinated, then $\lambda_{\max} = m$.

For small deviations, the compatibility condition $\lambda_{\max}$ value is close to m. *RI* – index (random), which is dependent on matrix sequence m and is presented in *Table 2*.

The compatibility ratio (13) derived from the formula is *CR* = 0,036. Thus, the compatibility ratio CR of the expert pairwise comparison matrix satisfies the established criteria: *CR* = 0.036 < 0.1. The data on assessing the influence of technical levels of technological devices on engineering competencies are summarised in *Table 6*.

Table 6 – Normalised data of the assessment of the influence of the technical level of technological devices on engineering competences

Data	**Overall**
Maximum eigenvalue $\lambda_{\max}$	8.361
Compatibility ratio *CR*	0.036

The compatibility ratio is *CR* = 0.036 < 0.1, and the maximum eigenvalue of the matrix is $\lambda_{\max}$= 8.36, which is close to the value 8, and adheres to the outlined conditions. Conclusion – expert opinions are consistent.

The linear function between technological innovations and engineering competencies determines the link between both criteria. The interconnection between introducing technological innovations (*y*) and the engineering competencies of logistics specialists (*x*) is demonstrated in *Figure 4*.

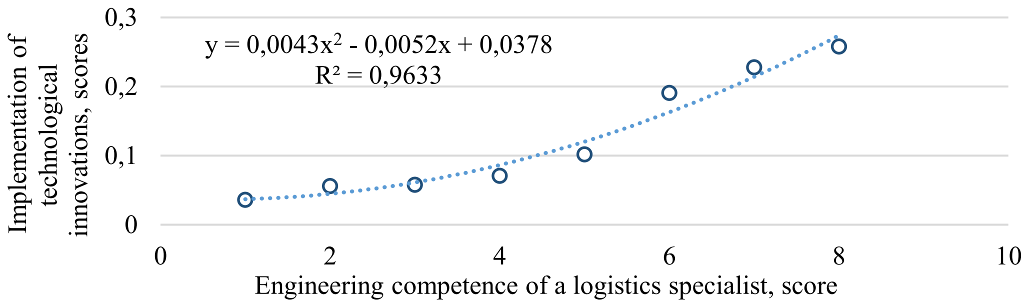

Figure 4 – Interconnection between the technological innovation development and the engineering competencies

The significance of technical levels of technological devices to impact engineering competencies is presented in *Table 7*.

Table 7 – Matrix outlining the effects of technical levels of technological devices on engineering competencies (compiled by authors)

Criteria of engineering competence	**Geometric mean**	**Normalised eigenvector**	**Rank**
I_1	0.068	0.071	5
I_2	0.054	0.056	7
I_3	0.056	0.058	6
I_4	0.036	0.036	8
I_5	0.250	0.258	1
I_6	0.221	0.228	2
I_7	0.185	0.191	3
I_8	0.099	0.102	4

The criterion estimates and the quadratic equation presented in *Figure 4* show that the increased technical level of technological equipment in railway enterprises has correspondingly increased the need for engineering competencies of logistics specialists. The analysis uses polynomial curve fitting. In this case, there is a strong correlation, R2=0.9633.

The data presented in *Table 7* show that the criteria (technical levels of technological devices) influencing engineering competencies are considered the most influential: digitalisation of rolling stock management systems I_5, management of technical maintenance and repair processes I_6 and familiarity with necessary procedures to follow in case of rail vehicle failures I_7.

The significance evaluation data on the following criteria – technical levels of technological devices and engineering competencies – are presented in *Table 8*.

Table 8 – Distribution of significance criteria of logistics specialists' engineering competences according to evaluations

Criteria	Expert								Sum of averages	Ranks
	E1	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**	**E8**		
I_1	0.004	0.007	0.014	0.004	0.004	0.014	0.014	0.011	0.009	5
I_2	0.003	0.006	0.011	0.003	0.003	0.011	0.011	0.008	0.007	7
I_3	0.003	0.006	0.012	0.003	0.003	0.012	0.012	0.009	0.007	6
I_4	0.002	0.004	0.007	0.002	0.002	0.007	0.007	0.006	0.005	8
I_5	0.013	0.026	0.052	0.013	0.013	0.052	0.052	0.038	0.032	1
I_6	0.011	0.023	0.046	0.011	0.011	0.046	0.046	0.034	0.029	2
I_7	0.010	0.019	0.038	0.010	0.010	0.038	0.038	0.029	0.024	3
I_8	0.005	0.010	0.020	0.005	0.005	0.020	0.020	0.015	0.013	4
Significance (weight)	0.050	0.100	0.200	0.050	0.050	0.200	0.200	0.150	–	–

According to the summarised data presented in *Table 8*, it was determined that the highest significance of evaluation criteria is assigned to the following engineering competencies (in descending order of importance): digitalisation of rolling stock management systems I_5, management of technical maintenance and repair processes I_6 and familiarity with necessary procedures to follow in case of rail vehicle failures I_7.

Experts also evaluated the impact of logistics cooperation and technological compatibility on the engineering competencies of logistics specialists. Expert consistency data are presented in *Table 9*.

The consistency ratio (*Table 9*) $CR = 0.031 < 0.1$, and the maximum eigenvalue $\lambda_{max} = 8.304$ is close to the value 8.0 and is in line with necessary conditions. Thus, expert opinions are in agreement.

Table 9 – Data on the impact of improving the harmonisation of logistics cooperation technologies on engineering competencies of logistic specialists

Data	Overall
Maximum eigenvalue λ_{max}	8.304
Consistency ratio CR	0.031

Table 10 presents the results from the expert evaluation of the criteria concerning the impact of improving the harmonisation of logistics cooperation technologies and engineering competencies of logistics specialists working in a railway transport company.

Table 10 – Distribution of the significance of the criteria for improving the compatibility of logistics cooperation technologies and engineering competencies of logistics specialists

Criteria	**Expert**									**Rank (sum)**
	E1 (LV)	**E2 (LV)**	**E3 (NL)**	**E4 (NL)**	**E5 (LT)**	**E6 (LT)**	**E7 (LT)**	**E8 (LT)**	**Suma**	
I_1	0.0014	0.0048	0.0048	0.0048	0.0048	0.0119	0.0081	0.0072	0.006	VIII
I_2	0.0015	0.0051	0.0051	0.0051	0.0051	0.0126	0.0086	0.0076	0.006	VII
I_3	0.0027	0.0089	0.0089	0.0089	0.0089	0.0222	0.0151	0.0133	0.011	V
I_4	0.0020	0.0067	0.0067	0.0067	0.0067	0.0168	0.0115	0.0101	0.008	VI
I_5	0.0030	0.0099	0.0099	0.0099	0.0099	0.0243	0.0169	0.0149	0.012	IV
I_6	0.0098	0.0326	0.0326	0.0326	0.0326	0.0815	0.0554	0.0489	0.041	I
I_7	0.0067	0.0223	0.0223	0.0223	0.0223	0.0557	0.0379	0.0334	0.028	II
I_8	0.0029	0.0098	0.0098	0.0098	0.0098	0.0249	0.0166	0.0146	0.012	III
Significance	0.03	0.1	0.1	0.1	0.1	0.25	0.17	0.15		1

According to summarised data presented in *Table 10*, it was determined that the highest significance is assigned to the following criteria (in descending order of importance): management of technical maintenance and repair processes I_6 – 0.041, familiarity with necessary procedures to follow in case of rail vehicle failures; I_7 – 0.028 and maintaining technological infrastructure in transport organisation I_8 – 0.012.

The significance data of the harmonisation of logistics collaboration technologies and engineering competencies of logistics specialists working in a railway transport company are presented in *Table 11*.

Table 11 – Matrix of the impact of improving the compatibility of logistics collaboration technologies on engineering competencies

Criteria of engineering competence	**Geometric mean**	**Normalised eigenvector**	**Rank**
I_1	0.047	0.048	8
I_2	0.049	0.052	7
I_3	0.087	0.089	5
I_4	0.065	0.067	6
I_5	0.097	0.097	4
I_6	0.319	0.326	1
I_7	0.217	0.223	2
I_8	0.096	0.098	3
Total	0.978	1	-

The linear function between the technological compatibility in logistics cooperation and the engineering competencies of logistics specialists is determined by the links between these two criteria. Interconnection between the advancing technological compatibility in logistics cooperation y and the engineering competencies x is presented in *Figure 5*.

The 2nd degree polynomial criteria estimates obtained from *Table 11* and *Figure 5* indicate that a sixfold increase in technological compatibility levels has correspondingly raised the demand for engineering competencies by 8 times. In this case, there is a strong correlation, R^2=0.9336.

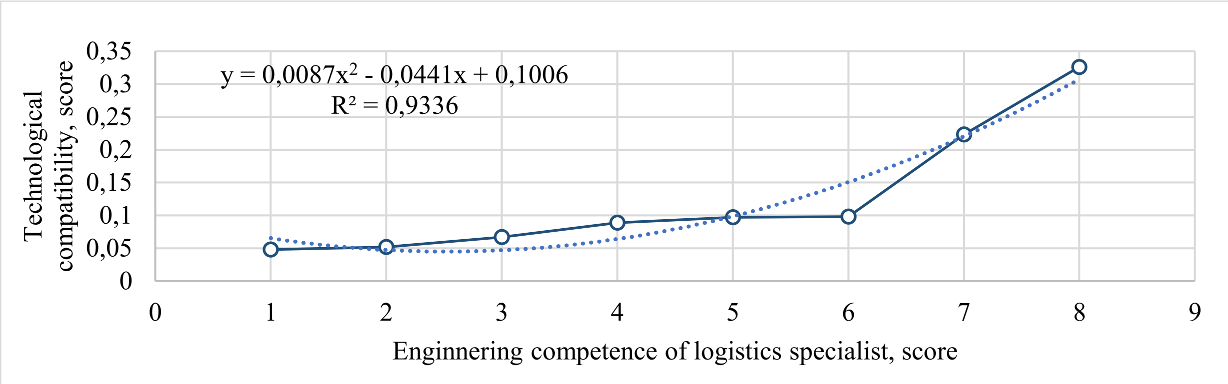

Figure 5 – Interconnection between the advancing technological compatibility in logistics cooperation and the engineering competencies

Experts were asked to assess which criteria are most important in improving the impact of raising the technical level of technological innovation implementation measures in railway companies on the engineering competencies of logistics specialists (1 – the most important; 8 – the least important). The distribution of expert ranks is presented in *Figure 6.*

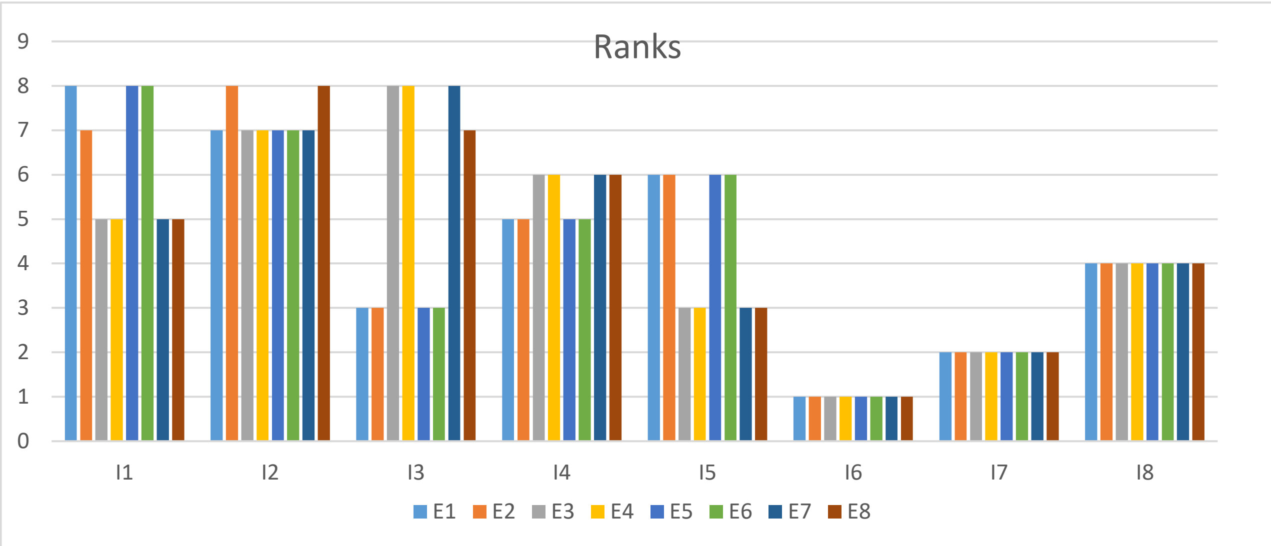

Figure 6 – Distribution of expert assessment ranks

Analysis and calculation data of the distribution of ratings of the 8th expert criteria are listed in *Table 12.*

The concordance coefficient W=0.752 was calculated according to *Equations 7–12*. The calculated value of χ^2 42.125 is greater than the critical value (14.0671); therefore, the average ratings indicate the general opinion of the experts, and the opinions of the responding experts are considered consistent. If the lowest value of the concordance coefficient W_{min}=0.2511<0.752, then the opinions of all 8 respondents on the 8 criteria are still considered reconciled. The confidence interval was calculated. The resulting confidence interval was [3.08; 1.78].

Table 12 – Data on the obtained ranks (compiled by the authors)

Mathematical expression	Criterion symbol (*m*=8)							
	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8
$\sum_{i=1}^{n} R_{ij}$	51	58	43	44	36	8	16	32
$\bar{R}_j = \frac{\sum_{i=1}^{n} R_{ij}}{n}$	6.38	7.25	5.38	5.50	4.50	1	2	4
$\sum_{i=1}^{n} R_{ij} - \frac{1}{2}n(m+1)$	15	22	7	8	0	-28	-20	-4
$\left[\sum_{i=1}^{n} R_{ij} - \frac{1}{2}n(m+1)\right]^2$	225	484	49	64	0	784	400	16

The impact of the importance of the technological indicators of railway companies affecting the engineering competencies of logistics specialists is calculated as Q_j. The data and all criteria, and their order from the least important to the most important, are presented in *Table 13.*

Table 13 – Results of criterion ranking (compiled by the authors)

Indicator marker	Criterion symbol (m=8)								
	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	Sum
q_j	0.1771	0.2014	0.1493	0.1528	0.1250	0.0278	0.0556	0.1111	1
d_j	0.8229	0.7986	0.8507	0.8472	0.8750	0.9722	0.9444	0.8889	7
Q_j	0.1176	0.1141	0.1215	0.1210	0.1250	0.1389	0.1349	0.1270	1
Q_j’	0.0729	0.0486	0.1007	0.0972	0.1250	0.2222	0.1944	0.1389	1
Distribution of the importance of the criteria	7	8	5	6	4	1	2	3	-

Based on calculations and expert assessments, the following order of importance of the criteria for assessing the impact of technological innovation of a railway company on the competencies of logistics specialists is presented:
1) I_6 – Management of technical maintenance and repair processes;
2) I_7 – Familiarity with necessary procedures to follow in case of rail vehicle failures;
3) I_8 – Maintaining technological infrastructure in transport organisation;
4) I_5 – Digitalisation of rolling stock management systems;
5) I_3 – Assessing completion of tasks and overall technical accuracy of achievements;
6) I_4 – Assessment and preparation of engineering documentation;
7) I_1 – Providing consultations on technological queries;
8) I_2 – Design of different assemblies, systems and compounds.

Both studies confirmed the influence of the railway company on the engineering competencies of logistics specialists. According to the data obtained, the criteria from I_3 to I_8 are arranged equally. The most important criteria are I_6 and I_7. Only the unimportant criteria I_1 and I_2 do not coincide.

Thus, the criterion values presented in *Table 4* and *Table 5* support the assertion that the indicators for assessing the correlation between the development of technological innovations and engineering competencies of logistics specialists, as detailed in *Table 1*, are suitably selected. The desire of railway transport companies to maintain a competitive advantage in the market encourages the implementation of technological innovations. The increasing development of technological innovations encourages the professional development of specialists. The productivity results of logistics specialists depend on their ability to adapt to the rapidly changing technological environment and update their knowledge and skills. The methodology for establishing and assessing the competencies of logistics specialists in railway undertakings (presented in *Figure 1*) has been modified to incorporate a key criterion: the implementation of technological innovations. The logical structure of the extended model for assessing the impact of innovations is presented in *Figure 7*.

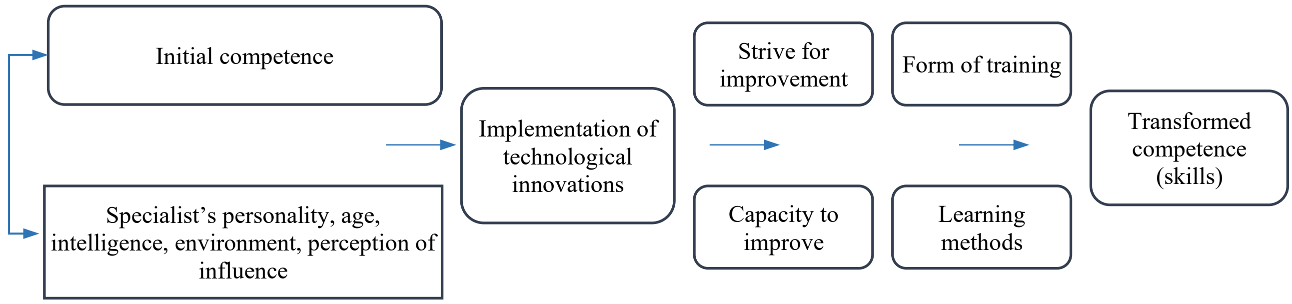

Figure 7 – Enhanced process of assessment of the competencies of logistics specialists in a railway undertaking (compiled by the authors)

According to data presented in *Figure 7*, it can be stated that implementing and obtaining new knowledge in the area of advanced technologies has the power to transform moral values, characteristics and ways of reasoning in each employee/specialist. The constantly changing labour market and technological advancements present new challenges, indicating that professional skills alone do not suffice for everyday functions. Developing additional skills is necessary for the management and control of new technological devices and/or systems.

To summarise, it has been identified that the synergy between engineering competencies and the development of technological innovations in railway undertakings impacts the technological infrastructure and the velocity of the rolling stock renewal.

The further development or updating of engineering competencies facilitates the effective use of the technological infrastructure in railway companies. The adoption of technological innovations in railway service companies fosters a more favourable economic landscape and ensures a more productive and harmonious environment for employees.

5. DISCUSSION

Wang et al. [52] utilised scientometrics to analyse the quantitative aspects of scientific communication, research and development practices, and the domains of science and technology. Based on the analysis of document models and characteristics, the researchers employed the Citespace tool to demonstrate that economic growth influences the adoption of transport technological innovations. Furthermore, the findings by Wang et al. [52] highlighted a couple of factors of technological development that are necessary to research and to evaluate, i.e. the interconnection of transport infrastructure technologies and social behaviour, economics and the environment. Researchers have extensively analysed the directions of technological change in the area of railway and other modes of transportation; however, they failed to evaluate the competencies of employees who shift in accordance with technological progress.

In their research on cooperation possibilities and other activities among transport companies, Zhao et al. [17] highlighted the principal evaluation criteria for implementing innovative technologies. It is the growth of innovations that result from inter-company cooperation that has the capacity to minimise environmental pollution on a global level. The factor for reducing environmental pollution in this research is assessed through the perspective of the ANS system. Researchers Cleophas et al. [16] described intermodal (different modes of transport) cooperation as the one that is linked by common technologies and systems. However, the competencies that are used to manage these systems were not addressed.

As noted by Ugur et al. [53], the impact of implementing technological innovations on company competitiveness emerges through changes in communication and consumption habits that these innovations bring about. This necessitates that employees adopt more advanced operation methods and innovative technologies and maintain a continual openness to innovation. The AHP method is applied to systematically evaluate the adoption of innovations and the capacity to effectively manage the latest (state-of-the-art) technological processes.

The introduction of technological advancements is establishing new pathways for the transportation of goods, thereby fostering innovative activities in railway undertakings and enhancing the attractiveness of their services to customers. This expansion of new channels is assessed through a labour demand model and innovation criteria in this research.

Research results demonstrate that in the context of developing technological innovations and implementing new information systems in railway undertakings, as well as rapid transmission of information and data processing, the competencies of logistics specialists alone are not sufficient. Information management with updated technologies rationalises the transportation process, thereby making it inevitable for logistics specialists to acquire engineering competencies. Development of engineering competencies ensures the productive use of innovative technologies and high levels of efficiency in transport organisations. According to Aloqaili et al. [54], the rapid and efficient execution of transportation processes necessitates that logistics experts in the transportation market utilise their technological and engineering knowledge to manage the transportation process effectively.

Research conducted by Christopher et al. [55] employs empirical methods to examine logistics activities in relation to strategic purchasing management, as well as the storage and movement of materials, components and finished goods. This research also addresses the associated information flows within the organisation and its marketing channels, emphasising the importance of cost-effectively fulfilling orders while maximising current profitability and achieving future financial success. Additionally, the competencies of a logistics specialist, operating as a service salesperson, are assessed in a rather subjective manner. A great deal of attention is devoted to the flexibility and retraining of a specialist; however, this approach is limited due to the failure to assess trends in technological changes and only the basic professional competencies are taken into account. The researchers have pointed out that current results are inconclusive and additional ones are on their way in the future. Researchers did not consider the ways in which investing in innovative technologies may impact the professional and engineering competencies of logistics specialists.

Scientist Pedron [56] argued that by entrusting the monotonous and physically demanding aspects of the logistics process to automation and assigning tasks that require creativity and emotional intelligence to technologically savvy employees, the overall quality of work was enhanced, while the burden on highly qualified specialists was alleviated.

The results of the study can be implemented to support the activities of innovative technological and staff qualification development decision-makers at the railway company. The undisputed connection between the efficiency of innovation implementation and the level of engineering competencies of logistics specialists is a strong argument for allocating funding and time to the competence development of company employees. Taking into account the expected innovations, qualification development programs are adjusted accordingly.

The authors of this paper intend to extend the scope of their research beyond multi-criteria evaluation methods. A more detailed analysis to assess the effects of the AI on the organisation of railway transportation is set to be carried out. The intention is to simulate a typical scenario that impedes the train traffic. Furthermore, future research is set to explore the synergy between the implementation of technological innovations and the competencies of logistics specialists in other modes of transport, including maritime and air transportation.

6. CONCLUSIONS

After analysing the concepts for technological innovation development proposed by experts from different scientific domains, it was found that the implementation of technological innovations entails the development of new information products and the upgrading of technical means. In addition to this, the necessity of quite fast implementation and integration of new control systems of rail vehicles and innovative technologies in transportation activities causes new challenges for railway undertakings.

The essential aspect influencing the demand for competencies among logistics specialists in railway undertakings is the implementation of technological advancements. The interdisciplinary decision-making by integrating technical, employee behaviour and decision-making strategic dimensions was used as the holistic feature of the AHP method. This AHP advantage ensures appropriate accuracy of evaluation as a whole interconnection of technical and social issues. The findings from the AHP evaluation of technological development in railway undertakings indicate a clear need for the timely enhancement of the engineering competencies of logistics specialists. Research further suggests that a fourfold increase in technological innovations within railway undertakings leads to an eightfold rise in the demand for developing these engineering competencies.

The developed methodology aimed at emerging and evaluating the engineering competencies of logistics specialists in railway undertakings has been expanded by integrating a criterion focused on the implementation of technological innovations.

It was determined that the improvement of technical levels of technological devices in railway undertakings has a great impact on engineering competencies of logistics specialists, causing they the need to continuously acquire new knowledge. The technical level augmentation of technological devices also leads to an amplified necessity for developing engineering skills and capabilities in logistics specialists. This trend is evident in such areas: first, the most important is the digitalisation of rolling stock management systems; second is the management of technical maintenance and repair processes; and third is the conversion of necessary procedures to follow in case of rail vehicle failures.

DISCLAIMER

The HE project PhDs EU-Rail (Grant number: 101175856). Funded by the European Union, Europe's Rail Joint Undertaking. Views and opinions expressed are, however, those of the authors only and do not necessarily reflect those of the European Union or Europe's Rail Joint Undertaking. Neither the European Union nor the granting authority can be held responsible for them.

Europe's Rail

Co-funded by the European Union

REFERENCES

[1] Mortensen PS, Bloch CW. *Oslo Manual-Guidelines for collecting and interpreting innovation data*. (Organisation for Economic Cooperation and Development); 2005. https://www.oecd.org/content/dam/oecd/en/publications/reports/2005/11/oslo-manual_g1gh5dba/9789264013100-en.pdf

[2] Loschky A. *Reviewing the nomenclature for high-technology – the sectoral approach. Luxembourg: Office for Official Publications of the European Communities 2010.* Luxembourg (Luxembourg): Publication Office of the European Union; 2010. DOI: 10.2788/73427

[3] Arifin Z, Frmanzah. The effect of dynamic capability to technology adoption and its determinant factors for improving firm's performance; Toward a conceptual model. *Procedia – Social and Behavioral Sciences.* 2015;207:786-796.

[4] Hagiu A, Altman EJ. Finding the platform in your product. *Harvard Business Review.* 2017;94-100.

[5] Heitmann F, Pahl-Wostl C, Engel S. Requirements based design of environmental system of systems: Development and application of a Nexus design framework. *Sustainability.* 2019;11(12):3464. DOI: 10.3390/su11123464

[6] Królczyk GM, et al. *Sustainable production: Novel trends in energy, environment and material systems.* Springer International Publishing; 2020. DOI: 10.1007/978-3-030-11274-5

[7] Vaičiūtė K, Katinienė A, Bureika G. The synergy between technological development and logistic cooperation of road transport companies. *Sustainability.* 2022;14(21):14561. DOI: 10.3390/su142114561

[8] *OECD Science, Technology and Industry Scoreboard 2015: Innovation for growth and society*. (2015, Oct 19). DOI: 10.1787/sti_scoreboard-2015-en

[9] Hirsch-Kreinsen H. Digitization of industrial work: Development paths and prospects. *Journal for Labour Market Research.* 2016;49:1-14. DOI: 10.1007/s12651-016-0200-6

[10] Walwei U. Digitalization and structural labour market problems the case of Germany. *International Labour Organization (ILO) Working Papers*, 994936693502676; 2016. https://www.ilo.org/sites/default/files/wcmsp5/groups/public/%40dgreports/%40inst/documents/publication/wcms_522355.pdf

[11] Nayan S, et al. The role of R&D expenditure on job creation in the Malaysian manufacturing sector. *International Journal of Supply Chain Management.* 2019;8(3):671-676. https://core.ac.uk/download/pdf/230742032.pdf

[12] Stevanović M, Stevanovic K. New directions in the design of railways stations. *GRAĐEVINAR.* 2014;66(8):739–747. DOI: 10.14256/JCE.975.2013

[13] Lovelace R, Parkin J, Cohen T. Open access transport models: A leverage point in sustainable transport planning. *Transport Policy.* 2020;97:47-54. DOI: 10.1016/j.tranpol.2020.06.015

[14] Bazaras D, Palšaitis R. Risk management in sea ports – insights and trends. *Proceedings of the 19th International Conference on Reliability and Statistics in Transportation and Communication (RelStat 2019)*, 16-19 Oct. 2019, Riga, Latvia. Cham, Switzerland: Springer; 2020. p. 268-274.

[15] Vasilis Vasiliauskas A, Vasilienė-Vasiliauskienė V, Čižiūnienė K. Solutions toward faster development of green warehouses in Lithuania. In: Bezpartochnyi M. *Transformation of international economic relations: modern challenges, risks, opportunities and prospects*. Collective monograph. Riga, Latvia: ISMA University; 2017.

[16] Cleophas C, Cottrill C, Ehmke JF, Tierney K. Collaborative urban transportation: Recent advances in theory and practice. *European Journal of Operation Research.* 2019;273(3):801-816. DOI: 10.1016/j.ejor.2018.04.037

[17] Zhao S, Qiu X, Lacey J, Maisch S. Configuring fixed-coefficient active control systems for traffic noise reduction. *Building and Environment.* 2019;149:415-427. DOI: 10.1016/j.buildenv.2018.12.037

[18] Stone DL, Deadrick DL, Lukaszewski KM, Johnson R. The influence of technology on the future of human resource management. *Human Resource Management Review.* 2015;25(2):216-231. DOI: 10.1016/j.hrmr.2015.01.002

[19] Bolodurina M, Mishurova A. Intellectualization of transport and logistics infrastructure agents network interaction through adaptive information and communication technologies introduction. *Proceedings of the 7th Scientific Conference on Information Technologies for Intelligent Decision Making Support (ITIDS 2019)*. Dordrecht, The Netherlands: Atlantis Press; 2019. p. 8-14. DOI: 10.2991/itids-19.2019.2

[20] Kostrzewski M, Filina-Dawidowicz L, Walusiak S. Modern technologies development in logistics centers: The case study of Poland. *Transportation Research Procedia.* 2021;55:268-275. DOI: 10.1016/j.trpro.2021.06.031

[21] Kaveckė I, Paužuolienė J. Environmental trends of transport companies and the possibility of moving to green logistics. *Regional Formation & Development Studies.* 2021;33(1):17-28. DOI: 10.15181/RFDS.V33I1.2196

[22] Taguma M, Feron E, Lim MH. Future of education and skills 2030. Conceptual learning framework. Concept note: Skills for 2030. *8th Informal Working Group (IWG) Meeting 29–31 October 2018.* Paris, France: OECD Conference Centre. 2018. https://static1.squarespace.com/static/5e26d2d6fcf7d67bbd37a92e/t/5e411f365af4111d703b7f91/1581326153625/Education-and-AI.pdf

[23] Berger T, Frey CB. Future shocks and shifts: Challenges for the global workforce and skills development: Key messages. *(OECD Internal Working document). 34.* Paris, France: OECD Conference Centre; 2015. http://www.oecd.org/education/2030-project/about/documents/Future-Shocks-and-Shifts-Challenges-for-the-Global-workforce-and-Skills-Development.pdf

[24] Becker GS. *Human capital: A theoretical and empirical analysis, with special reference to education.* Chicago: University of Chicago Press; 1993. DOI: 10.7208/chicago/9780226041223.001.0001

[25] Ledauskaitė K. *Economic assessment of the human resources potential of the transport sector. Doctoral dissertation [Transporto sektoriaus žmogiškųjų išteklių potencialo ekonominis vertinimas. Daktaro disertacija].* Vilnius: Technika; 2010.

[26] Geistmann C. *Interkulturelle Kompetenz - Eine wichtige förderbare Fähigkeit in der internationalen Zusammenarbeit.* Norderstedt: Demand GmbH; 2002.

[27] Dulewicz V. Assessing leadership styles and organisational context. *Journal of Managerial Psychology.* 2005;20(2):105-123. DOI: 10.1108/02683940510579759

[28] Laužackas R. *Vocational training methodology: monograph [Profesinio rengimo metodologija: monografija].* Vytautas Magnus University [Vytauto Didžiojo universitetas]; 2000. https://hdl.handle.net/20.500.12259/41757

[29] Martinkienė J. Application of managerial competencies in a business practical training firm. Management. [Vadybinių kompetencijų taikymas verslo praktinio mokymo firmoje]. *Scientific research papers [Vadyba. Mokslo tiriamieji darbai].* 2009;1(14):79-87.

[30] Chlivickas E, Papšienė P, Papšys A. Žmogiškieji ištekliai: strateginio valdymo aspektai. *Verslas, vadyba ir studijos. Business Management and Education*. 2009;8(1):51-65. DOI: 10.3846/bme.2010.04

[31] Juodeikaitė, M, Fominienė A. Assessment of changes in human resource management processes: theoretical and practical aspects. [Žmogiškųjų išteklių valdymo procesų pokyčių vertinimas: teorinis ir praktinis aspektas]. *Information Sciences [Informacijos mokslai].* 2016;74:25-37.

[32] Chowdhury T, Murzi H. The evolution of teamwork in engineering workplace from first industry revolution to industry 4.0: A literature review. *ASEE Virtual Annual Conference.* Virginia Tech (Virginia Polytechnic Institute and State University); 2020. DOI: 10.18260/1-2--35318

[33] Savanevičienė A, Stukaitė D, Šilingienė V. Development of strategic individual competences [Development of strategic individual competences]. *Engineering Economics.* 2008;58(3):81-88.

[34] Knowles-Cutler A, Lewis H. Talent for survival: Essential skills for humans working in the machine age. Deloitte. 2016. https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/Growth/deloitte-uk-talent-forsurvival-report.pdf

[35] Dittrich PJ. *Reskilling for the fourth industrial revolution: Formulating a European strategy.* Berlin: Jacques Delors Institute; 2016.

[36] Tsekeris C. Surviving and thriving in the fourth industrial revolution: Digital skills for education and society. *Homo Virtualis.* 2019;2(1):34-42. DOI: 10.12681/homvir.20192

[37] Nuthall PL. *Farm Business Management: The Core Skills.* Cambridge: CABI; 2010.

[38] Korucuk S, Aytekin, A. Assessing the problems encountered by companies using e-logistics via a Polytopic fuzzy methodology: A case of Giresun province. *Spectrum of Engineering and Management Sciences*, 2024;*2*(1):36-45.

[39] Attah RU, Garba BMP, Gil-Ozoudeh I, Iwuanyanwu O. Strategic frameworks for digital transformation across logistics and energy sectors: Bridging technology with business strategy. *Open Access Research Journal of Science and Technology*. 2024;12(2):70-80.

[40] Rosi M, Obrecht M. Insights into sustainability integration and top priorities for green and digital transition in logistics. *Proceedings–The First International Conference FUTURE-BME*. 2024. DOI: 10.24867/FUTURE-BME-2024-001

[41] Nold M, Corman F. How will the railway look like in 2050? A survey of experts on technologies, challenges and opportunities for the railway system. *IEEE Open Journal of Intelligent Transportation Systems.* 2024;5:85-102. DOI: 10.1109/OJITS.2023.3346534

[42] Wahab SN, Tan A, Roche O. Identifying supply chain manager leadership skills and competencies gaps in Malaysia. *Higher Education, Skills and Work-Based Learning*, 2024;14(5):921-937.

[43] Susanto PC, Sawitri NN, Ali H, Rony ZT. Analysis of competency and job satisfaction on the performance of warehouse staff in logistics companies in Jakarta. *Proceedings of the International Conference on Humanity Education and Society (ICHES 2024)*. 2024;3(1).

[44] Saaty, TL. *The analytic hierarchy process.* New York: McGraw-Hill. 1980. DOI: 10.1002/0470011815.b2a4a002

[45] Podvezko V, Sivilevičius H. The use of AHP and rank correlation methods for determining the significance of the interaction between the elements of a transport system having a strong influence on traffic safety. *Transport.* 2013;28(4):389-403. DOI: 10.3846/16484142.2013.866980

[46] Sivilevičius H, Maskeliūnaitė L. The criteria for identifying the quality of passengers' transportation by railway and their ranking using AHP method. *Transport.* 2010;25(4):368-381. DOI: 10.3846/transport.2010.46

[47] Galindo-Rueda F, Millot V. Measuring design and its role in innovation. OECD Science, Technology and Industry Working Papers. 2015;01. Paris, France: OECD Publishing; 2015. DOI: 10.1787/5js7p6lj6zq6-en

[48] Maskeliūnaitė L, Sivilevičius H. Identifying the importance of criteria for passenger choice of sustainable travel by train using ARTIW and IHAMCI methods. *Applied sciences*. 2021;11(23):11503.

[49] Soria-Lara JA, Banister D. Evaluating the impacts of transport backcasting scenarios with multi-criteria analysis. *Transportation Research Part A: Policy and Practice*. 2018;110:26-37.

[50] Jūras D, Radzevičienė A. Impact of business partnership crisis on management in aviation companies. *Science: Future of Lithuania/Mokslas: Lietuvos Ateitis*. 2022;14.

[51] Bazaras D, Išoraitė M, Vaičiūtė K. A study of the relationship between marketing and investment in technology development in transport company. *Sustainability*. 2020;14(19):12927.

[52] Wang L, Xue X, Zhao Z, Wang Z. The impacts of transportation infrastructure on sustainable development: Emerging trends and challenges. *International Journal of Environmental Research and Public Health.* 2018;15:1172. https://www.ncbi.nlm.nih.gov/pubmed/29874785

[53] Ugur M, Churchill SA, Solomon E. Technological innovation and employment in derived labour demand models: a hierarchical meta-regression analysis. *Journal of Economic Surveys.* 2018;32(1):50-82.

[54] Aloqaili S, Alharthy R, Alsaudon S, Alshaalan R. *Technology in work place.* Riyadh, Saudi Arabia: College of Business Administration. Princess Nourah bint Abdulrahman University; 2019. https://www.researchgate.net/publication/342106878_Technology_in_the_Workplace

[55] Christopher M. *Logistics and supply chain management.* London: Financial Times/Prentice Hall; 2016.

[56] Pedron Z. The skills revolution of the 21st century: It's time to re-calibrate. *On Research (Journal of EU Business School).* 2018;1:20-28. https://at.onresearch.ch/wp-content/uploads/2019/01/Research-Journal.ONRESEARCH.1st-Issue.pdf#page=20