

REQUIRED TECHNICAL COMPETENCIES NECESSARY FOR PROFESSIONAL PRACTICE IN INDUSTRIAL ENGINEERING AND MANAGEMENT

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Abstract

This article addresses the evolving demands placed on industrial engineers and managers within the context of rapid organizational and technological advancements, specifically influenced by factors arising from the social, legislative, economic, and technological environments. The core of the study lies in identifying the essential technical and practical competencies required for successful application in modern industrial engineering and industrial enterprise management. Technological progress, marked by widespread digitalization, is fundamentally altering the character of engineering work, shifting focus towards advanced data analysis, simulation, software proficiency, and predictive control.

Key words: *business management, digitalization, engineer competencies, industrial engineering, process optimization*

JEL Classification M1, M12, O3, C44

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INTRODUCTION

Industrial engineering is a field that is constantly evolving. The requirements for industrial engineers are shaped by organizational development, which is influenced by various external factors resulting from the development of the social, legislative, economic and technological environment. Technological progress is not only changing the work of workers in industry, but also the character of the work of an engineers. Digitalization allows for various analyses and simulations, but also increases the need to control and perform these analyses, with the need for predictive management coming to the fore. In particular, industrial engineers should be able to ensure the production and standard course of processes and procedures taking place in production. The main task of process engineers is to optimize processes in production, whether in terms of their efficiency, quality or cost. For this important role, it is necessary for industrial engineers and managers to have the necessary skills that take into account all aspects of an industrial engineer's job.

THEORETICAL BACKGROUND

Managers of industrial enterprises face many challenges regarding the effective management of industrial enterprises. Addressing inefficiencies is particularly crucial in the early stages of processes, as it can lead to substantial cost reductions, which is already evident in the current industrial environment (Dulina et al., 2025). Effective resource management is a critical challenge. Efficient resource allocation is intended to reduce costs and increase profits. Successfully overcoming these challenges requires the use of advanced intelligent information systems that optimize costs, production time, and profits (Al-yasin et al., 2025). The implementation of advanced systems enables real-time control and monitoring of industrial processes. New technologies make it possible to move the industrial agenda far beyond the capabilities of conventional systems through digitization. Advanced real-time data analytics make it possible to improve efficiency and productivity in industries in particular (Nechibvute & Mafukidze, 2024). The technological side in the management of industrial enterprises is often emphasized in connection with the introduction of smart industry (Moraes et al., 2023). Traditional production processes are gradually being replaced by smart technologies. Smart manufacturing systems make it possible to leverage IT and collect large amounts

of data in real time, which are then analyzed to make accurate decisions and predict future outcomes in order to improve the efficiency of manufacturing operations. However, coordination between machines and humans is essential for effective functioning. This is made possible by large-scale data analysis, which makes the methods of analysis and productivity of production units simple and fast (Gupta et al., 2022). Organizations must adapt to rapidly evolving technologies, which requires the need for systems engineering, robust information management, and collaboration. However, key engineering skills must also mature to achieve the desired result (Kempton & Waldon, 2024). The integration of new technologies, or the combination of technologies, can bring major benefits to the industry in increasing data transparency and efficiency. However, there are still some challenges that need to be addressed, such as the interoperability of individual data protection and security systems, and the need for qualified personnel (Dwivedi et al., 2024). The introduction of intelligent industry elements into organizations has an impact not only on the operation of industrial enterprises, but also on the people who work in them. The need for qualified workers is growing and employers' demands for a higher level of education are also growing. Technological changes require in particular vocational training and the development of technical skills. Increasing the professionalism of employees can enable them to cope with new technologies in the best possible way (Grenčíková et al., 2021). Industrial engineers have a major impact on the functioning of enterprises and the introduction of smart industry. Their competencies have a positive impact on the implementation and management of smart industry technologies. The most important competencies related to production security and prediction of the development of production scenarios, reflecting technological progress and introducing technologies were demonstrated. In the context of intelligent industry, the importance of competencies related to automation and robotization, or cloud solutions, is growing in importance (da Rocha et al., 2025). Among education experts and specialists in the field of intelligent industry and Industry 4.0, discussions are still ongoing about the new challenges of Industry 4.0 for industrial engineers. Despite these discussions, there is no consensus on which competencies are required of industrial engineers to face these new challenges (Rosas Quintero & Namuche Maldonado, 2024). Technical skills remain at the core of engineering despite the fact that the working conditions and tasks of engineers have changed and the so-called hard engineering is shifting to the so-called soft engineering (Nguyen, 1998). In engineering, emphasis is placed on practical engineering as an integrated competence that appears to be the most important integrated design capability (Suleiman & Abahre, 2020). In order for technological progress and its potential to be fully exploited, it is not enough to have integrated high-quality technologies, but it is also necessary to have people who will enable the use of these technologies and their proper functioning (Hitka et al., 2023). The ability to work with modern technologies, but also the ability to use digital tools for process control to analyze data and is becoming an essential skill for future professionals (Bolek, 2025). Therefore, it is important that engineers and industrial managers in industrial enterprises in particular have competencies that are important for the correct deployment of technologies and the functioning of processes in the organization.

OBJECTIVE AND METHODOLOGY

Given the importance of technical competencies for the work of a manager, we decided to examine which technical competencies are considered important by employers. Technical competencies were divided into two groups, namely I. Technical operational competencies and II. Technical conceptual competencies. For the purposes of the study, we set three research questions:

RQ1: What are the current technical competencies requirements for industrial engineers and managers?

RQ2: To what extent are technical competencies of industrial engineers and managers required in industrial enterprises in Slovakia?

RQ3: How do the technical competencies requirements for industrial engineers and managers differ?

The aim of the presented study was to analyze the current priorities in the requirements for the technical competencies of industrial engineers and managers of industrial enterprises. For the study, we chose a qualitative design and a descriptive approach. Advertised job descriptions and job vacancy requirements specifications in the field of industrial engineering and management were analyzed for the purpose of the

study. The advertisements were obtained from advertising portals in Slovakia. The collection of advertisements took place in the period February 2025 – April 2025. The selection criterion was that the advertisements contained requirements for positions that were denoted as "Industrial Engineer" or "Process Engineer" or "Industrial Manager". For the purpose of the study, 40 advertisements were searched. Each advertisement was transcribed into a structured database in MS Excel. Relevant sections on the job description, powers and responsibilities and requirements for the applicant were extracted from the texts of the advertisements. Subsequently, a qualitative analysis of the content was carried out in the form of a thematic analysis. Based on reading and analyzing the texts of the advertisements, coding was done. Competency categories have been created for similar codes. Based on the results of profiling the competencies of industrial engineers and managers, we determined their importance according to which competencies were repeated most often. To interpret the results, we chose descriptive statistics in the form of tables. In Table 1, we can see a description of the structure of the examined sample of 40 job advertisements.

Table 1: Number of jobs hired

Job Title	Absolute abundance	Relative abundance [%]
Industrial Manager	8	20.00
Process Engineer	17	42.50
Industrial Engineer	15	37.50
Total	40	100.00

Source: own processing, 2025

Table 1 shows that a total of 40 advertised jobs were analysed. The highest number was 17 jobs – Process Engineer (42.5%) and the smallest number was for the job position – Industrial Manager (20%).

RESULTS AND DISCUSSION

Empirical research aimed at identifying key technical competencies was carried out through a detailed content analysis of advertised job positions on leading Slovak professional portals. As previously stated, the analytical efforts focused on three key professional profiles: industrial engineer, process engineer and industrial manager. The initial step of the analysis was to map the regional distribution of the data obtained, as the demand for specific engineering competencies is closely related to the concentration of industrial production in individual parts of Slovakia. The geographical structure of the examined sample of 40 job advertisements, divided by individual self-governing regions, is clearly illustrated in Table 2.

Table 2: Distribution of analysed job advertisements by region

Region	Absolute abundance	Relative frequency [%]
Banská Bystrica	12	30.00
Bratislava	4	10.00
Košice	2	05.00
Nitra	3	07.50
Prešov	1	02.50
Trenčín	10	25.00
Trnava	5	12.50
Žilina	3	07.50
Total	40	100.00

Source: own processing, 2025

The data presented in Table 2 show that the most significant representation in the demand for industrial engineers and managers is shown by the Banská Bystrica Region with a share of 30.00% (12 advertisements), closely followed by the Trenčín Region, where 25.00% (10 advertisements) of the total volume of job vacancies were identified. A significant part of the labour market in this area is also represented by the Trnava Region (12.50%) and the Bratislava Region (10.00%). On the contrary, the lowest offer of vacancies meeting the selection criteria was recorded in the Košice Region (5.00%) and the Prešov Region, which makes up only 2.50% of the research sample with one advertisement. These results reflect the regional concentration of industrial companies and automotive clusters, which naturally show a higher demand for experts in the field of industrial engineers.

Evaluation of RQ1: *What are the current technical competencies requirements for industrial engineers and managers?*

As part of the processing of the results related to the first research question, an in-depth thematic analysis of the texts of the advertised job positions was carried out. Based on the coding of employers' requirements, it was found that the demands on the technical readiness of applicants are naturally concentrated in mutually complementary areas. As a key theoretical and practical result of this phase of research, the division of technical competencies into two main thematic groups was defined: (1) Technical operational competencies and (2) Technical conceptual competencies. When evaluating the research question, we first focused on Technical operational competencies, which are necessary to ensure the proper functioning of production operations.

Table 3: Overview of identified Technical operational competencies

Code	Category / Area of competence	Detailed description of the requirements from the advertisements
A	Device management and setup	Planning and ensuring the correct operation of technological and additional equipment, setting the parameters of machines and equipment.
B	Product launch	Introduction and classification of new products into serial production, component quality planning (CQA process) and pricing.
C	Technological support and testing	Control of technological processes and technical support, selection and implementation of appropriate technological procedures and performance of technological tests.
D	Process development and optimization	Planning, development and classification of new production processes, definition and optimization of process parameters.
E	Renewal of machinery	Participation in the selection of new machines and equipment, installation of new equipment and their introduction into operation.
F	Design solutions	Design and implementation of new structural solutions of jigs.
G	Metrology and quality	Security, definition and analysis of measuring instruments and measurement systems.

Source: own processing, 2025

From the data in Table 3, it is clear that technical operational competencies were divided into seven separate categories marked with codes A to G based on thematic analysis. The assigned coding creates a systematic basis for an exact evaluation of the frequency of occurrence of individual requests in the next phases of the analysis. From the point of view of the job description, the dominant feature of these competencies is their direct connection to ensuring the stability, quality and fluency of the physical course of the production process.

Following on from the previous breakdown, Table 4 presents six categories of Technical conceptual competencies, which have been coded H to M. Technical conceptual competencies are important primarily in the design of workplaces and for the implementation and improvement of processes.

Table 4: Overview of identified Technical conceptual competencies

Code	Category / Area of competence	Detailed description of requirements from advertisements
H	Design and ergonomics	Workplace design, layout changes based on the principles of ergonomics and occupational health and safety, creation of material flows.
I	Performance Management (KPIs)	Support for defining, implementing, and tracking KPI metrics for processes with a focus on quality, productivity, and cost.
J	Strategic maintenance planning	Participation in the design of the strategy and the creation of plans in the field of maintenance, modernization and renewal of machines.
K	Tool and inventory management	Creating a list of tools, monitoring their stock levels and collaborating on ordering new ones.
L	Change Management	Planning and implementing changes in production.
M	Process monitoring and stability	Monitoring, analysis and evaluation of configured production and non-production processes, analysis of process stability, control of compliance with parameters.

Source: own processing, 2025

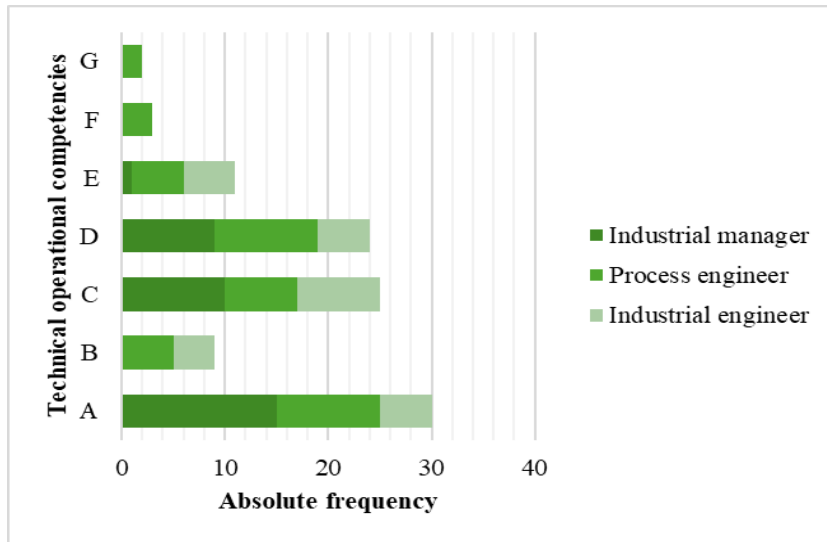
The competencies listed in Table 4 reflect the shift from purely operational activities to a systemic understanding of an industrial enterprise, dominated by the spatial arrangement of flows (code H) and strategic planning of innovation (code J). An important component of this group is the emphasis on data-driven management through the introduction of KPI metrics (code I) and continuous evaluation of process stability (code M). Together, these components define the analytical profile of an industrial engineer or manager who is able not only to keep production systems running, but also to systematically develop them and manage their changes.

Evaluation of RQ2: *To what extent are technical competencies of industrial engineers and managers required in industrial enterprises in Slovakia?*

To determine the extent and degree of demand for individual technical skills, the absolute frequency of occurrence of codes in 40 collected advertisements was analyzed. The results of this analysis are broken down into two main groups of competences and visualised in the attached graphs (Figure 1 and Figure 2). A graphical representation of the absolute frequency of occurrence of individual operational competencies in the analysed advertisements is provided in Figure 1. The identified competencies are marked on the vertical axis of the graph with codes A to G, which correspond in meaning and content to the detailed categorization given in the previous Table 3.

Figure 1 graphically illustrates the absolute frequency of demand for Technical operational competencies (codes A to G from Table 3) within the 40 advertisements analysed, visually distinguishing the contribution of the three monitored job positions. From an overall point of view, the competency of equipment management and setup (code A) dominates, with the highest incidence at the level of 30 records, where a significant share is the position of Industrial manager, followed by a balanced demand for technological support (code C) and process development (code D), where the Process engineer is strongly represented. On the contrary, the lowest overall frequency within the entire sample is reported by the areas of design solutions (code F) and metrology (code G), which do not appear in the offers for industrial managers at all and are only minimally represented in process and industrial engineers. The composition of the individual columns thus clearly confirms that while the operational core A, C, D is universally required across all three professions, specific activities such as the introduction of new products (code B) are the domain of process and industrial engineers only.

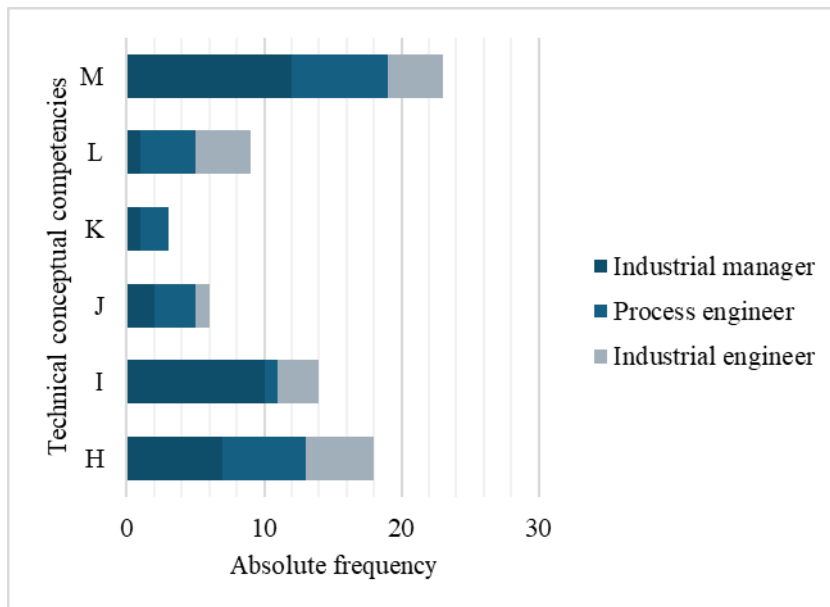
Figure 1: Absolute frequency of requests for Technical operational competencies by job position



Source: own processing, 2025

After the analysis of engineering activities, the attention of the study shifts to the second, strategic-analytical dimension of labor market requirements. For a comprehensive view of the qualification profile, it is necessary to examine the scope of demand for system competencies, which have been defined in the methodological part as Technical conceptual competencies. The distribution of the absolute abundance of these competencies and their distribution among individual job positions is illustrated in Figure 2, while the designations H to M used on the vertical axis of the graph directly refer to the six conceptual categories described in detail in the previous Table 4.

Figure 2: Absolute frequency of requests for Technical conceptual competencies by job position



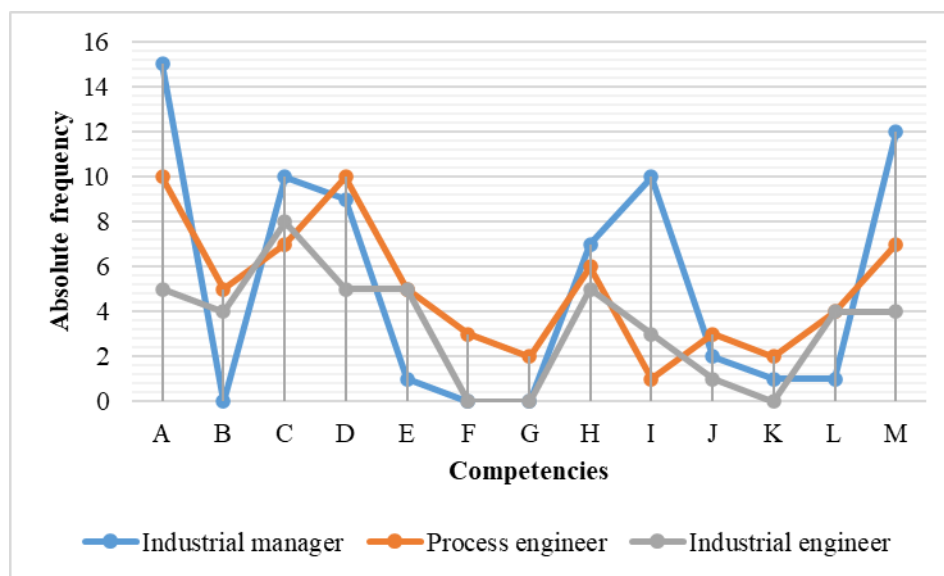
Source: own processing, 2025

Figure 2 demonstrates the absolute abundance of technical conceptual competency requirements (codes H to M from Table 4), revealing a clear dominance of two key areas. The highest frequency of occurrence is achieved by competence M focused on monitoring, analysis and stability of processes with a total of 23 records, closely followed by the H coding, which represents the design of workplaces and material flows with 18 occurrences. From the point of view of the structure of job positions, it is clear that while process analysis (code M) and layout changes (code H) show a balanced demand across all three professions, the area of performance management and KPI metrics (code I) is mostly required for the position of Industrial manager with 14 occurrences. At the opposite end of the spectrum, with minimal interest from employers, was tool and inventory management (code K), which achieved only 3 occurrences, while in advertisements for industrial engineers (Industrial engineer) this requirement is completely absent, as well as strategic maintenance management (code J).

Evaluation of RQ3: *How do the technical competencies requirements for industrial engineers and managers differ?*

To answer the third research question, we used a comparative analysis to identify specific differences and priorities in employers' requirements for the three monitored professional profiles: Industrial manager, Process engineer and Industrial engineer. To accurately capture these differences, the distribution of all thirteen identified competencies was monitored at the same time. A summary view of demand variability and mutual differences in the profiles of individual positions is provided in Figure 3, where designations A to G represent technical operational competencies (from Table 3) and designations H to M represent technical conceptual competencies (from Table 4).

Figure 3: Comparison of the absolute frequency of required competencies by job position



Source: own processing, 2025

The visual comparison in Figure 3 reveals significant differences in the profiles of labour market demands, with the most significant anomalies being shown by the position of Industrial Manager. Three competencies in particular are critical for this managerial role: plant operation and setup (code A, 15 occurrences), process monitoring and stability (code M, 12 occurrences) and performance management through KPI metrics (code I, 10 occurrences), while narrowly focused engineering activities such as new product introduction (code B) or tool management and design (codes F, G, K), They are completely absent

from managers. On the other hand, the process and industrial engineer profiles show a high degree of synergy in the graph and follow a similar course of curves. A more significant differentiation between them occurs in code D (Planning and development of new production processes), where employers place significantly higher emphasis on process engineers (10 occurrences compared to 5 occurrences in industrial engineers), and code C (Control of technological processes), where industrial engineers slightly dominate. The resulting comparative graph thus clearly proves that while engineering positions are primarily focused on technical implementation, process development and solving specific technological tasks, the profile of an industrial manager is strictly shaped by the market towards executive stability management, performance control and achievement of set goals.

However, for all three analysed professions, primary technical competencies are important for these professionals to be applicable and successful in professional practice.

Highly qualified employees are consistently in demand across all industries. Low-skilled and semi-skilled workers are only relevant in specific sectors, such as end-user customer service in the manufacturing sector (e.g. clothing, furniture and consumer electronics). In the manufacturing sector, a massive shift in job requirements (low-skilled and semi-skilled workers) is expected due to technological changes involving the Internet of Things, cloud technologies, and big data analytics. To some extent, polarization in the manufacturing sector can be determined by job competencies and the level of automation (Janis & Alias, 2018). However, a significant shortage of technological skills competencies has been identified in various sectors. A growing lack of competence in terms of quantity but also quality, which has an impact on innovation and the competitiveness of enterprises. Competency shortages are not only a short-term but also a medium-term challenge for businesses (Ebert & Hemel, 2023).

The competency challenges for new technologies are multifaceted and include the integration of advanced technologies as well as addressing educational gaps.

CONCLUSIONS

Cooperation between universities and practice plays an important role in the preparation of future industrial engineers and managers, correcting the requirements for the content focus of the study. However, solid theoretical training requires the application of various forms of education, enabling participation in the solution of specific practical problems and the development of practical skills and lifelong learning. The management of industrial enterprises must also focus on developing qualified personnel and ensuring the safe and efficient introduction of new technologies to maintain competitiveness and promote innovation.

The results of our analysis clearly show that academic training must reflect the dual nature of labour market expectations, which requires graduates not only to master traditional operational activities, but also to an increasing extent to conceptual and analytical thinking. The connection between the academic environment and the industrial sphere should therefore focus more intensively on the development of skills in the field of data analytics, monitoring KPI metrics and designing modern ergonomic workplaces. Graduates with this combination of knowledge are able to respond much more flexibly to the regional needs of companies, which is also confirmed by the high concentration of demand for these experts, especially in the Banská Bystrica and Trenčín regions. Under the influence of digitalization, conventional engineering is thus turning into a complex managerial and technological system, in which the success of an organization directly depends on the readiness and continuous development of its human capital. The results of our analysis confirm that the labor market requires a dual graduate profile, where traditional operational skills must intertwine with conceptual thinking, data analytics and change management. It is this flexibility that is the key to meeting the needs of businesses, especially in the industrially strong Banská Bystrica and Trenčín regions.

The main limitation of the submitted study is the size of the research sample (40 advertisements) and its time limit to a three-month period of 2025, which limits the full generalization of the results. In addition, the analysis is based exclusively on the texts of the advertisement, which may not one hundred percent

reflect real everyday practice. Future research should therefore focus on expanding the sample and integrating a questionnaire survey or guided interviews directly with experts from industrial companies.

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