



Integrated balanced scorecard model for production safety incorporating the Industry 4.0 perspective

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Abstract

The aim of this study was to develop a five-layer balanced scorecard (BSC) model for production safety, expanded to include a digital perspective consistent with the Industry 4.0 concept and to develop a strategy map. This approach enables the integration of strategic and operational objectives, the identification of cause-and-effect relationships, and their mapping within the structure of key performance indicators (KPIs). The research used a literature review, a conceptual approach, and elements of systems modelling. The research was carried out in close collaboration with a manufacturing company, allowing the adaptation of the developed model based on actual process data and its partial verification in a production environment. This solution increased the applicability of the proposed approach. The research results indicate that expanding the classic Balanced Scorecard with a digital component enhances the company's ability to make sound decisions in conditions of rapid development and high technological risk.

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1. Introduction

The growth of modern manufacturing companies is driven by the need to ensure high quality standards, ever-increasing competition, pressure to improve operational efficiency, and the need to maintain stable production process safety (Yang et al., 2025; Fan et al., 2022). At the same time, enterprises operating in the industrial sector are forced to respond to changing technological, market and regulatory conditions, which implies the implementation of modern tools that support strategic and operational management (Pogodina et al., 2022; Czerwińska and Pacana, 2022). The integration of various areas of the enterprise, including technological processes, risk management, human resources and environmental aspects, is becoming particularly important (Sa et al., 2025; Ingaldi and Ulewicz, 2025; Ingaldi and Ulewicz, 2020).

A major challenge in the management of modern organisations is ensuring consistency between the strategic and operational levels, particularly in matters relating to production safety. The growing complexity of technological processes, their high level of automation, and the presence of a large number of risk factors mean that safety management should not be treated as a separate area, but should be viewed as an

integral part of the enterprise management system (Pitelinsky et al., 2025; Klimecka-Tatar and Niciejewska, 2021). This approach requires the use of tools that enable the simultaneous monitoring of a significant number of operational aspects, along with their interrelationships, thereby facilitating the identification of cause-and-effect relationships and the making of appropriate management decisions (Di Paco et al., 2026; Gajdzik, 2014).

One of the tools that supports a comprehensive approach to management is the Balanced Scorecard (BSC), which enables the translation of a company's strategy into a set of measurable objectives and key performance indicators (Krylov, 2025; Dagidir and Ozkan, 2024). The approach is based on analysing the organisation from complementary perspectives, which most commonly include the financial perspective, internal processes, customers, and development (learning and growth). This concept makes it possible not only to monitor current performance effectively, but also to identify cause-and-effect relationships between activities carried out in different areas of the organisation (Alanazi, 2025; Ulewicz et al., 2023). In practice, the BSC is a tool that integrates strategic objectives with operational activities and supports decision-making processes (Quesado et al., 2025; Krynke, 2023).



The aim of this study was to develop a five-layer model of a balanced scorecard for production safety, extended to include a digital perspective in line with the Industry 4.0 concept, and to develop a strategy map illustrating the cause-and-effect relationships between the analysed perspectives.

2. Literature review

The concept of the strategic scorecard is seen as a means of improving performance and eliminating errors arising from inefficient company management (Armijos et al., 2025; Liao et al., 2025, Dobrovič, et al., 2018). The method combines the process of strategy formulation with that of its implementation, as it serves not only to make optimal choices and implement strategies, but also to communicate management's expectations and measure progress towards strategic objectives (Lucyanda et al., 2025). The balanced scorecard is recommended as an effective tool for improving business performance by promoting a holistic approach to performance management that is geared towards sustainable growth (Vuong, 2025; Koleci, 2025).

A consequence of the BSC-based approach adopted is the need to operationalise the strategy set out therein, which implies the use of appropriate tools to measure and monitor its implementation. In this regard, indicators that enable the ongoing assessment of the extent to which set objectives are being achieved and the effectiveness of the actions taken become particularly important (Larsson et al., 2025).

Key performance indicators (KPIs) are the foundation for the effective use of the BSC in industrial enterprises, as they enable strategic objectives to be translated into measurable operational results. The selection of KPIs should be closely linked to the adopted analysis perspectives, which will ensure consistency between the adopted strategy and the activities carried out at various levels of the enterprise (Pacana and Czerwińska, 2023). It is important that each KPI is directly linked to the adopted strategic objective and allows for the monitoring of progress in its implementation (Pacana and Czerwińska, 2020). At the same time, each of the BSC perspectives requires the use of specific KPIs that are appropriate to the nature of the company's operations (Martynenko et al., 2020; Zani et al., 2022; Krynke, 2023).

In the practice of manufacturing companies, we are increasingly seeing modifications to the traditional perspectives of the balanced scorecard. This is achieved by incorporating a sustainability perspective (Dagidir and Ozkan, 2024), as well as modifications to the BSC related to eco-management, leading to the creation of Green Balanced Scorecard (GBSC) models (Pham et al., 2025) or the development of the Sustainability Balanced Scorecard (SBSC) (Lucyanda et al., 2025). Academic studies also point to the integration of the Sustainable Development Goals (SDGs) with the balanced scorecard, identifying evolutionary trends (Quesado et al., 2025; Garafalakis et al., 2025). The direction of BSC development in industrial enterprises points to its transformation from a performance monitoring tool into a comprehensive strategic management system, taking into account the organisation's

impact on its environment. This implies adapting it to prevailing trends in industrial practice and the need to design KPIs that not only measure operational efficiency but also support long-term value in environmental and social dimensions.

With the development of digital technologies in manufacturing environments and the growing popularity of the Industry 4.0 concept, the standard BSC framework needs to be updated and expanded. Modern industrial enterprises are increasingly adopting solutions characteristic of this concept, such as the Internet of Things (IoT), artificial intelligence, real-time data analysis and systems integrating IT and OT environments (Czerwińska et al., 2025; Velinov & Konovalova, 2022; Ingaldi & Ulewicz, 2026). These technologies are transforming the way production processes are carried out and influencing safety management methods by enabling a shift from a reactive to a predictive and proactive approach (Miskiewicz and Wolniak, 2020; Krynke, 2021). In response to current trends in industry, it makes sense to expand the classic balanced scorecard structure to include an additional digital perspective. This additional perspective will enable the consideration of a company's level of digitalisation, the integration of systems, and the use of analytical tools to support production safety management (Krynke, 2021).

Incorporating an additional digital perspective into the BSC allows for a more comprehensive representation of how modern industrial enterprises operate and enables the management model to be better aligned with digital transformation. Furthermore, in the context of ensuring efficiency within production safety management, it is appropriate to replace the customer perspective with an environmental/operational perspective, which better reflects the conditions of industrial enterprises and emphasises the importance of safety aspects and the impact on the environment. This approach forms the foundation for developing extended BSC models that integrate technological, organisational and operational aspects, supporting effective production safety management in the face of the growing complexity of digitalised production processes.

3. Method

The balanced scorecard provides a comprehensive overview of the effectiveness of the company's strategy, taking key perspectives into account. It should be emphasised, however, that this is not a method used to develop an organisation's strategy. The strategy serves as the starting point for creating a balanced scorecard. The development of the scorecard is used to monitor the implementation of the adopted strategy and enables its improvement. The process of creating and applying a balanced scorecard is illustrated in Figure 1.

The development of a balanced scorecard should be preceded by the establishment of a task force responsible for coordinating and overseeing the implementation of the entire process. It is advisable for the team to include representatives from various levels of management and different areas of the organisation. A diverse team composition helps to ensure that multiple perspectives are taken into account and improves the accuracy of the decisions made.

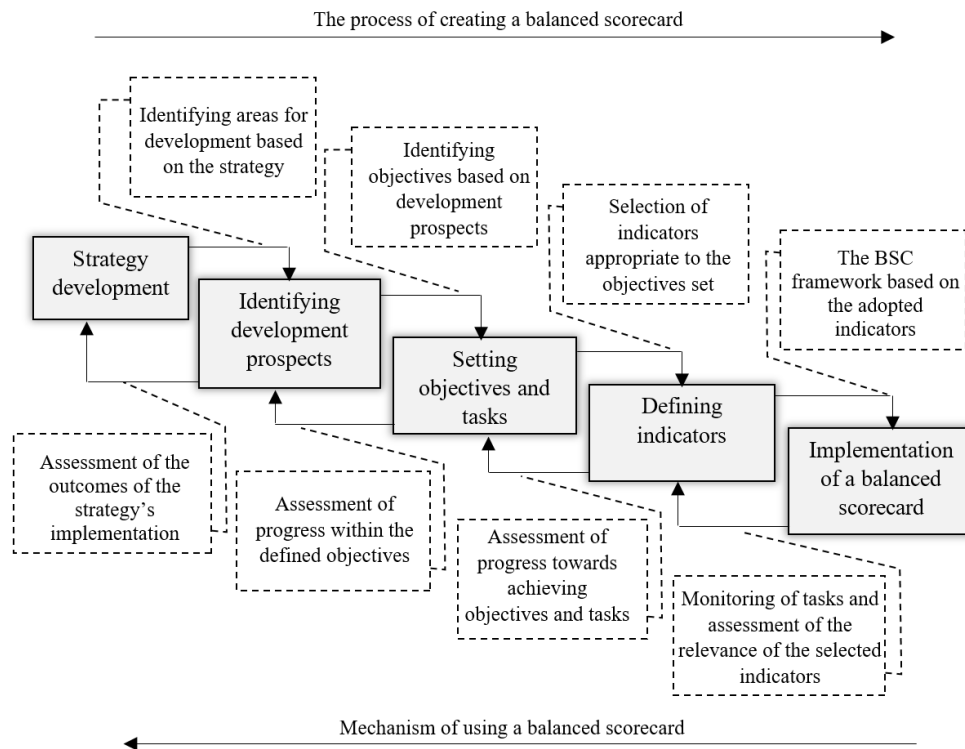


Fig. 1. The concept of developing and implementing a balanced scorecard

The work of the appointed team should begin with the development of a new or in-depth analysis of the organisation's existing vision, mission and strategy. This stage is of key importance, as it forms the foundation for formulating coherent operational and strategic objectives, which are then cascaded down to the level of departments, teams and individual employees. It is important to ensure alignment between objectives at different levels of the organisation, as this supports the effective implementation of strategic objectives.

The next key step is to identify and define in detail the objectives and tasks that stem from the strategy. Objectives are formulated within the framework of four classic perspectives, namely customer, finance, internal processes and development (learning), as well as (in response to contemporary conditions and industry trends) within the framework of an additional digital perspective, which is consistent with the Industry 4.0 concept. Supplementing the classic perspectives with a digital perspective enables a comprehensive analysis and integration of issues relating to digital transformation, automation and the use of data in the management of an industrial enterprise.

Each of the defined objectives should be assigned appropriate Key Performance Indicators (KPIs) that allow for a quantitative or qualitative assessment of the level of their achievement. When selecting indicators, consideration should be given to data availability, unambiguous interpretation and a close link to strategic objectives. On this basis, a balanced scorecard is created, which is a structured set of objectives, indicators and improvement initiatives.

The management process does not end with the implementation of a balanced scorecard. It requires systematic monitoring and regular review. Continuous analysis of target achievement and the relevance of indicators enables the rapid identification of deviations and the implementation of appropriate preventive and corrective actions. The need for modification may arise, amongst other things, from errors at the design stage, inappropriate setting of target levels, changes in the industry and market environment, dynamic competitive conditions, as well as the occurrence of unforeseen events.

As a result of the correct and consistent use of the balanced scorecard, management gains not only a control tool but also a comprehensive system supporting strategic management. It enables ongoing control over the implementation of tasks and objectives, oversight of the relevance of indicators in a changing industrial environment, and monitoring of progress within the analysed perspectives; ultimately, it allows for the verification of the effects of implementing an industrial enterprise's strategy.

4. Results and discussion

The research was conducted in close collaboration with an industrial foundry company based in south-eastern Poland. This enabled the development of a model based on the specific characteristics of the actual production processes and the organisational and technological conditions of the entity under analysis. The research utilised process data relating, amongst other things, to equipment operating parameters, safety-re-

lated incidents and selected environmental aspects. This approach enabled the model structure (a correlated strategic map with an extended version of the sustainable scorecard) and the proposed KPIs to be appropriately adapted to the company's operating conditions. The approach adopted helped to preserve the model's applicability and ensured its alignment with industrial practice, whilst enabling a preliminary assessment of its usefulness in supporting decision-making processes in the field of production safety.

Following the developed model requires the identification of a set of KPIs that enable the measurement, analysis and assessment of production safety levels within a foundry. The selection of appropriate indicators was carried out taking into account the specific nature of the company and the foundry processes carried out there, which are characterised by a significant level of technological risk, associated, amongst other

things, with the effects of high temperatures, working with molten metal and the emission of harmful substances.

The set of KPIs was developed based on the principles and logic of the balanced scorecard, taking into account both financial and non-financial indicators assigned to the key perspectives of the company's operations. The classic approach is complemented by the digital perspective (Industry 4.0), which highlights the significant role of modern technologies in monitoring, analysis and decision support in the area of safety, as well as in the digital transformation of enterprises.

Table 1 presents the set of KPIs developed, which provides a summary of the key indicators that determine the level of production safety in a foundry. The table also includes an interpretation of the indicators and outlines the potential uses of digital tools to support their measurement and analysis.

Table 1. Key performance indicators in the BSC model for production safety, with an extension to include the digital perspective

BSC perspective	KPI	Unit	Reasons for the choice	The use of Industry 4.0 technology
Financial	Cost of workplace accidents	PLN / year	The direct impact of safety on costs	Integration with ERP systems and cost data analysis
	Cost of furnace downtime	PLN / hour	A critical cost in foundry operations	Real-time furnace monitoring (IoT)
	Cost of non-conforming castings	PLN / year	The link between quality and process safety	Quality analysis systems based on AI and computer vision
Internal processes	Number of accidents (LTI)	number	A key safety indicator	Digital incident reporting and analysis systems
	Number of near-miss incidents	number	Early identification of risks	Mobile apps and reporting platforms
	MTBF for furnaces and machinery	hours	Reliability of critical equipment	Predictive maintenance (IoT, AI)
	MTTR (mean time to repair)	hours	Efficiency of response to breakdowns	CMMS/MES systems supporting maintenance management
Employees	Number of specialist health and safety training courses	number / year	Critical factors when working with molten metal	VR/AR training and e-learning platforms
	Accident-related absence rate	percent	Consequences of hazardous incidents	HR analytics systems
Environmental	Emissions of dust and gases	mg/m ³	One of the main hazards in foundries	Environmental sensors and real-time emissions monitoring
	Level of employee exposure to harmful factors	mg/m ³ / ppm / °C	The direct impact of environmental conditions on workers' health and safety	Workplace monitoring systems (IoT, wearable sensors)
	Number of predictive failure alerts	number	Early detection of hazards	AI / Machine Learning algorithms
Digital (Industry 4.0)	Response time to threats	second	Key to minimising the impact of incidents	Real-time analytics systems
	Level of digitalisation of security processes	percent	The extent to which digital solutions have been implemented	Integration of MES, SCADA and IoT systems
	Proportion of automatically detected incidents	percent	The effectiveness of threat detection systems	AI, computer vision, detection systems
	Level of IT/OT system integration	percent	The consistency of data flow within the organisation	ERP-MES-SCADA integration

The set of KPIs presented in Table 1 reflects a comprehensive approach to production safety management in an industrial enterprise, taking into account the specific nature of the technological processes carried out and potential hazards. Extending the classic balanced scorecard structure by incorporating an additional digital perspective (Industry 4.0) highlights the significance of this element within modern enterprise management systems. This approach enables a comprehensive assessment of the level of production safety, the company's technological maturity, and the effectiveness of Industry 4.0 tools within its management framework. The addition of this perspective goes beyond the traditional approach of merely monitoring current events. It enables the prediction of risks and the proactive implementation of preventive measures, which significantly strengthens the enterprise's ability to effectively manage safety in a digital environment.

In the context of KPI-based management, the 'Industry 4.0 Adoption' column (Table 1) is also of significant importance, as its contents highlight potential technological solutions that support the management process through KPIs. The proposed tools, such as IoT systems, artificial intelligence, real-time data analytics, and MES and ERP systems, enable automation in data collection, enhance data reliability, and allow for a reduction in response times to emerging threats. Thanks to the implementation of Industry 4.0 tools, KPIs cease to serve a purely monitoring function and instead form part of a dynamic decision support system.

The integration of indicators with digital solutions supports the development of a data-driven management environment, within which it is possible to identify cause-and-effect relationships and continuously improve processes. As a result, the developed set of KPIs can serve not only as a tool for monitoring and assessing safety levels, but also as a basis for implementing improvement and optimisation measures, as well as for enhancing an industrial enterprise's resilience to technological risks.

The set of KPIs presented in Table 1 serves as a starting point for analysing the interrelationships between the various areas of production safety management. While defining the indicators themselves is important in terms of measuring effectiveness, it does not fully capture the dynamics of a safety system based on the interrelationships and interactions between processes, technology and resources.

To illustrate these relationships and identify the mechanisms through which key factors (defined by the KPIs) influence the level of production safety, a strategy map has been drawn up using the balanced scorecard approach (Figure 2). The map developed enables the mapping of cause-and-effect relationships between the KPIs included in the individual perspectives, indicating how actions implemented at the technological and operational levels translate into the results achieved by the company.

The structure of the strategy map (Figure 2) reflects a logical cause-and-effect relationship, whereby actions taken at lower levels determine the outcomes achieved at higher levels.

The starting point for analysing the relationships and mechanisms through which key factors influence production safety levels is the employees' perspective (Figure 2). This includes

indicators such as the number of specialist health and safety training sessions and the accident-related absence rate. These KPIs reflect the level of risk awareness, competence and employee engagement in identifying hazardous situations. An increase in the number of training sessions helps to reduce the number of actual accidents and stabilise operational processes.

The internal processes perspective (Figure 2) includes key operational indicators such as: the number of near-miss incidents, MTBF for furnaces and machinery (mean time between failures), MTTR (mean time to repair), and the number of accidents (LTI). The values of these indicators are directly influenced by activities undertaken as part of hazard identification and human resource management. The near-miss indicator has been assigned to the internal processes perspective, as it reflects the effectiveness of the hazard detection and reporting system, whilst being strongly linked to the level of employee engagement and awareness (the employee perspective). Increased equipment reliability (MTBF) and reduced response times to breakdowns (MTTR) lead to a reduction in the number of accidents and incidents and, consequently, improved production continuity.

An important element of the strategy map (Figure 2) is the digital perspective, which is closely linked to current trends in the manufacturing sector associated with the Industry 4.0 concept. This perspective serves an integrating and supporting function for the other areas. It includes operational indicators such as the number of predictive failure alerts and response time to threats, as well as indicators of digital maturity, including the level of IT/OT system integration, the level of digitisation of safety processes, and the proportion of events detected automatically. The extent of IT/OT system integration is a prerequisite for the digitisation of security processes, which in turn enables the implementation of advanced mechanisms for the automatic detection of incidents. Consequently, an increase in the digital maturity of an industrial enterprise leads to more effective threat identification and a reduction in operational risk. A carefully selected set of indicators within the digital perspective enables a shift from a reactive to a predictive and proactive strategy, which enhances the effectiveness of threat identification and supports real-time decision-making.

The environmental perspective focuses on two complementary indicators: emissions of dust and gases, and the level of worker exposure to harmful factors. The first KPI indicates the impact of foundry operations on the external environment, whilst the second indicator relates directly to working conditions and worker health. Taking both KPIs into account provides a more complete picture of the relationship between the working environment and production safety. It also indicates that reducing emissions and monitoring exposure levels contribute to reducing health risks, lowering staff absenteeism, and improving the overall level of safety and operational stability of the company. The indicator measuring the level of employee exposure to harmful factors in the presented framework of interdependencies acts as an intermediate link between pollutant emissions and the health consequences for staff and operational consequences.

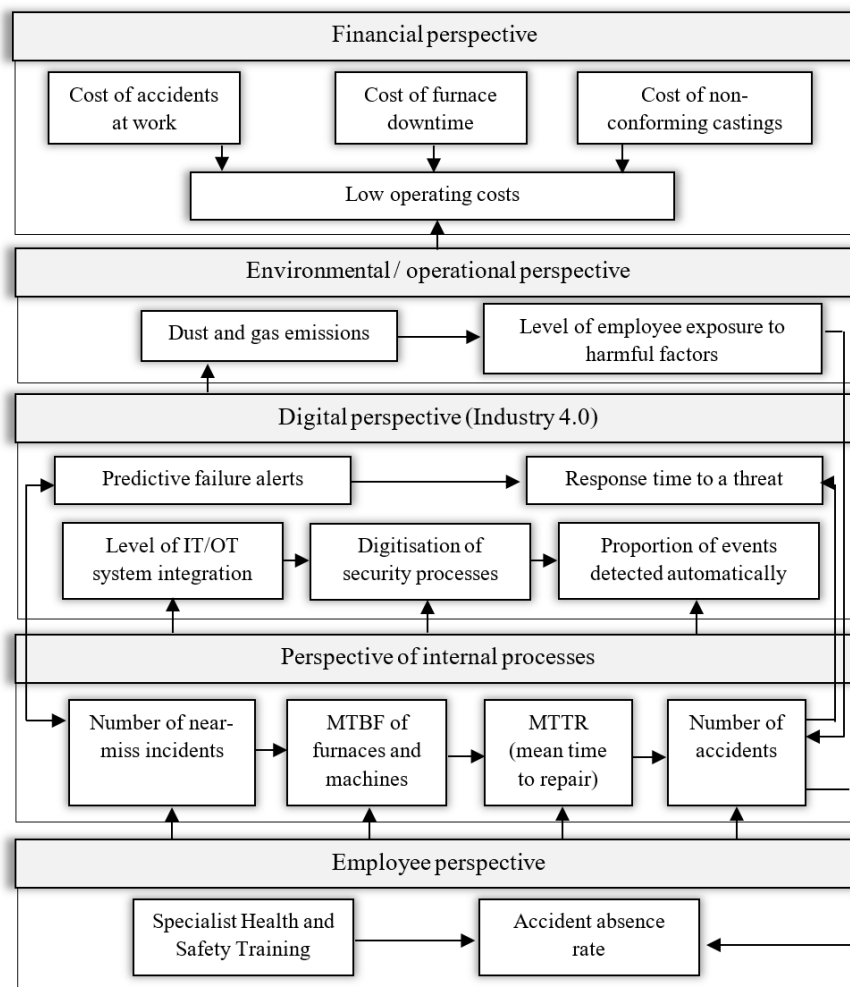


Fig. 2. Strategy map for production safety in a foundry

At the highest level of the strategy map (Figure 2) is the financial perspective, which takes into account the costs of workplace accidents, furnace downtime and casting shortages. The KPIs listed here provide a summary of the effectiveness of the measures implemented at lower levels. Improvements in production safety, increased process reliability and the use of digital technologies contribute to a reduction in financial losses (low operating costs) and an increase in the operational efficiency of an industrial enterprise.

The use of a strategy map allows for a clear illustration of the cause-and-effect relationships between the specified perspectives and key performance indicators. This approach facilitates a better understanding of the mechanisms that shape the level of production safety. Visualising these relationships aids the accurate identification of key areas for intervention, which supports decision-making processes and promotes the implementation of a data-driven management approach. Consequently, this approach leads to increased efficiency and resilience of an industrial enterprise against technological risks.

To determine the level of safety before and after the implementation of the presented model, a production safety index (WBP) was developed – a composite indicator that aggregates

the values of defined KPIs from a multi-perspective approach. This approach enables the comparison of indicators with different units and a comprehensive assessment of the level of production safety. The construction of the WBP involved three stages.

KPI normalisation (step 1) involves converting the values of individual indicators to a uniform, dimensionless scale $\{0;1\}$, where: 0 – very poor; 1 – very good, using appropriate mathematical relationships. For indicators where a higher value is favourable (stimulants: number of near-miss incidents, mean time between failures, number of health and safety training sessions, number of predictive failure alerts, level of digitisation of safety processes, proportion of automatically detected incidents, level of IT/OT system integration), the following formula is applied:

$$x_i = \frac{\text{the value achieved} - \text{minimum value}}{\text{maximum value} - \text{minimum value}} \quad (1)$$

For indicators where a lower value is desirable (destimulants: number of accidents, time taken to rectify faults, accident-related absence rate, emissions of dust and gases, level of employee exposure to harmful factors, cost of workplace accidents, cost of furnace downtime, cost of non-conforming

castings, response time to hazards), the following formula is used:

$$x_i = \frac{\text{maximum value} - \text{the value achieved}}{\text{maximum value} - \text{minimum value}} \quad (2)$$

Step 2 involves assigning weights to individual KPIs, reflecting their importance in assessing the level of production safety. In this study, it has been assumed that all KPIs have equal weighting, which allows the model to remain neutral. This means that each indicator contributes equally to the final value of the WBP indicator.

It should be emphasised, however, that in industrial practice, weights may be defined on a case-by-case basis for a given company. The determination of weights may be based on expert knowledge using multi-criteria methods such as AHP, fuzzy AHP, ANP or DEMATEL. Additionally, sensitivity analysis enables the assessment of the impact of changes in weights on the final value of the WBP index and the identification of indicators of greatest significance for production safety. Assigning different weights to individual KPIs allows for a better reflection of the actual significance of the analysed safety areas under the specific operating conditions of a manufacturing company. In practice, however, not all indicators have the same impact on safety levels; therefore, greater weight can be assigned to KPIs related to critical processes, the risk of failure or employee safety.

However, the study opted to apply uniform KPI weights, which allowed the model to retain its universal and neutral

character and simplified the calculation procedure. This approach also facilitates the implementation of the model and its adaptation across various manufacturing companies, regardless of their organisational and technological characteristics.

Step 3 involves calculating a synthetic production safety index by aggregating the normalised values of the individual KPIs. If equal weights are applied to all indicators, the index value is determined as the arithmetic mean of their normalised values, according to the formula:

$$WBP = \frac{1}{n} \sum_{i=1}^n x_i \quad (3)$$

where: x_i – normalised value of the i -th KPI, n – number of indicators analysed.

In general terms, taking the weights into account, the index can be expressed as:

$$WBP = \sum_{i=1}^n w_i \cdot x_i \quad (4)$$

Assuming equal weights, the following holds: $w_i = \frac{1}{n}$, which simplifies the calculations to an arithmetic mean. This approach ensures transparency and makes the results easy to interpret, whilst enabling a comprehensive assessment of production safety levels based on a wide range of indicators.

For the calculation of the PSS indicator, the values of individual KPIs were collected and analyzed. Table 2 presents the normalized values of the KPIs divided into stimulants (↑) and destimulants (↓).

Table 2. Normalisation of the identified KPIs

KPI	Value		Before implementation	x_i before	Following implementation	x_i after
	Min	Max				
Cost of workplace accidents (↓)	200	500	420	0.27	280	0.73
Cost of furnace downtime (↓)	400	700	650	0.17	480	0.73
Cost of non-conforming castings (↓)	700	1000	900	0.33	720	0.93
Number of accidents (LTI) (↓)	5	15	12	0.30	8	0.70
Number of near-miss incidents (↑)	20	80	45	0.42	78	0.97
MTBF for furnaces and machinery (↑)	100	200	120	0.20	165	0.65
MTTR (mean time to repair) (↓)	3	8	6	0.40	4	0.80
Number of specialist health and safety training courses (↑)	10	35	18	0.32	30	0.80
Accident-related absence rate (↓)	3	6	5.2	0.27	3.8	0.73
Emissions of dust and gases (↓)	50	100	85	0.30	65	0.70
Level of employee exposure to harmful factors (↓)	50	80	70	0.33	55	0.83
Number of predictive failure alerts (↑)	10	50	15	0.13	42	0.80
Response time to threats (↓)	60	150	120	0.33	70	0.89
Level of digitalisation of security processes (↑)	30	80	45	0.30	70	0.80
Proportion of automatically detected incidents (↑)	20	70	30	0.20	65	0.90
Level of IT/OT system integration (↑)	30	80	40	0.20	75	0.90

The data presented in Table 2 relate to a specific manufacturing company and are provided by way of example. The main aim of this study is to present the proposed methodology; the numerical values themselves are of secondary importance. The actual KPI values should be entered individually by the users of the model, which will enable a proper assessment of

the safety level and the implementation of rational improvement measures tailored to the specific characteristics of the company in question.

In step 2, which involves assigning weights, the study assigned equal weights to all KPIs, meaning that each KPI has an identical impact on WBP:

$$w_i = \frac{1}{16} = 0.0625 \quad (5)$$

In step 3, the WBP index is calculated:

- calculating the sum of all normalised KPI values (x_i):
before implementation: $\sum x_i = 4.17$ (6)
following implementation: $\sum x_i = 12.86$ (7)
- calculation of WBP:
before implementation: $WBP = \frac{4.17}{16} = 0.28$ (8)
following implementation: $WBP = \frac{12.86}{16} = 0.80$ (9)

The interpretation of the safety level result was based on the ranges shown in Table 3.

Table 3. Interpretation of WBP results

WBP	Security level	Description
0 - 0.04	low	High risk, lack of effective process control, predominance of reactive measures.
0.04 – 0.70	medium	Partial process control; the safety system requires further improvement.
0.70 – 1.00	high	Effective safety management, a proactive approach and the use of digital tools.

The results obtained indicate a marked improvement in production safety, as evidenced by the rise in the WBP ratio from 0.28 to 0.80. This change reflects a significant reduction in operational risk and an improvement in the stability of production processes. The result achieved also indicates better control over processes, an increase in the effectiveness of preventive measures, and an improvement in the company's ability to identify and minimise risks.

5. Summary and conclusion

The aim of the research was to develop an integrated model of a sustainable scorecard for production safety, which takes into account both strategic and operational aspects of management, whilst addressing the challenges associated with the digital transformation of enterprises in the context of Industry 4.0. The research was designed to present a tool enabling decision-making in conditions of increased technological risk and dynamic changes in production processes within enterprises in the foundry industry.

As part of the research, a set of key performance indicators (KPIs) was developed based on the principles of a balanced scorecard, extended to include a digital perspective, reflecting current trends in industrial enterprises. Furthermore, a strategy map was created which defines the relationships between KPIs and enables the identification of mechanisms through which key factors influence production safety levels. The developed map enables the mapping of cause-and-effect relationships between the KPIs included in the individual perspectives, indicating how actions implemented at the technological and operational levels translate into the results achieved by the company.

The proposed model may be useful for production managers, industrial safety specialists and analysts involved in risk and process management within industrial enterprises. Future research will focus on adapting the model to the specific characteristics of various industrial sectors and on analysing the impact of organisational culture and employee competencies

on the effectiveness of implementing the concept of an extended balanced scorecard in industrial practice.

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