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A MODEL FOR SHAPING REVERSE LOGISTICS IN MANUFACTURING COMPANIES USING INDICATOR ANALYSIS

Karolina CZERWIŃSKA[1], Andrzej PACANA[2*], Arkadiusz RZUCIDŁO[3], Ryszard RADWAŃSKI[4]

[1] Rzeszow University of Technology, Faculty of Mechanical Engineering and Aeronautics; k.czerwinska@prz.edu.pl, ORCID: 000-0003-2150-0963
[2] Rzeszow University of Technology, Faculty of Mechanical Engineering and Aeronautics; app@prz.edu.pl, ORCID: 0000-0003-1121-6352
[3] Rzeszow University of Technology, Faculty of Mechanical Engineering and Aeronautics; k.czerwinska@prz.edu.pl, ORCID: 0000-0002-1080-6150
[4] Association of Veterans and Reservists of the Polish Army in Warsaw; ryszard.radwanski@vip.onet.pl, ORCID: 0000-0002-2100-6845
* Correspondence author

Purpose: The aim of the study was to modify the classic SCOR model to include a key area for manufacturing companies (quality control) and to propose a herarhical set of key performance indicators designed to measure the implementation of selected processes in line with reverse logistics and the idea of sustainable development.
Design/methodology/approach: The study addresses the topics of indicator analysis and sustainability in the context of quality control implementation. The developed set of metrics was based on a modified SCOR supply chain model taking into account quality control and reverse logistics.
Findings: Using the assumptions of the SCOR model in constructing a set of metrics allows it to be extended in the context of key supply chain links as well as defining hierarchical performance measurement.
Research limitations/implications: A limitation of the proposed model was the lack of consideration of important business processes (sales, marketing, product development). The SCOR model lacks a link to the strategy and objectives of the supply chains considered. Further research will look at extending the model with missing elements and detailing the quality control process as envisaged by the SCOR model at level two adequately to the types of quality control occurring in the manufacturing space (input, inter-operational and final quality control).
Practical implications: The proposed universal set of indicators and yardsticks is intended to enable its implication in manufacturing enterprises in the form of a traditional model (no recycling) or under conditions of reverse logistics application. The model makes it possible to compare the two options and choose the more efficient one.
Social implications: The developed model for analysing the efficiency of one link in the supply chain allows the efficiency of reverse logistics to be monitored, which is closely related to the implication of the concept of sustainability in manufacturing enterprises.

Originality/value: Modification of the SCOR supply chain model to include quality control and the return aspect in the production context. Based on which, a proprietary set of indicators was developed.
Keywords: Mechanical engineering, manufacturing enterprise, SCOR model, quality control, circular economy, logistics security.
Category of the paper: Research paper, Viewpoint.

1. Introduction

Increasing globalisation and the dynamic development of new industrial and information technologies are a source of radical changes in manufacturing, planning and control systems (Stawiarska et al., 2021). Growing in global markets, manufacturing companies have the latest production and automation technologies at their disposal, as well as extensive communication networks and sophisticated computer software to integrate resources, which significantly assists in making appropriate business decisions (Czerwińska et al., 2024a). Nowadays, with similar technology and comparable quality of products, goods and services provided by business entities, both IT systems, ways of controlling production processes and the need to coordinate decisions made by all members involved in the supply chain are gaining importance (Ulewicz, Blaska, 2018; Pacana, Czerwińska, 2023a). The synchronisation of activities and the fulfilment of quality characteristics contribute to increasing the quality of manufactured products, increasing productivity, reducing inventory levels while maintaining high standards of customer service (Wolniak, 2021; Czerwińska et al., 2024b).

The increase in the intensity of competition is, among other things, resulting in an increase in customer demands for environmental care. When considering the formation of the concept of sustainability in the production space, the terms sustainable consumption and sustainable production emerge (Gajdzik, Wolniak, 2022; Diaconeasa et al., 2022). Sustainable consumption and sustainable production are two areas of activity with a significant impact on the economy of any country, especially a developed one. Sustainable consumption does not necessarily mean reducing the level of consumption intensity - it should be closely linked to efficiency. Both sustainable production and consumption require economic actors, public administration, households to intervene to increase the quality of the natural environment through the realisation of efficient production, minimisation of the consumption of natural resources, minimisation of waste generation and optimisation of production processes (Papamichael et al., 2024; Glavic, 2021). One specific definition of sustainable production defines it as the search for value-adding technologies that meet the needs of buyers while minimising material use and maximising process efficiency. The need to use raw materials efficiently is a result of their limited quantity. Sustainable production represents the next stage of change and development in the global organisation of production after the period of craftsmanship, mass production and flexible production systems (Kumawat et al., 2021; Greenland et al., 2023). Loss reduction and recycling, which are the pillars of sustainable production, are also important in terms of sustainability (Lim et al., 2025; Kar, Harichandan, 2022). Loss reduction refers to reducing the generation of production waste, post-production waste and packaging materials, while recycling recovers already used natural raw materials (Czerwińska et al., 2024). Efficient sourcing of waste materials and raw materials for reuse belongs to the area of reverse logistics. Material flow management ends when non-hazardous product residues are returned to nature or raw materials are reused - we are talking about a closed product life cycle (Rossi et al., 2025; Uniyal et al., 2021; Pacana et al., 2020).

The success of the implications of the sustainability concept depends on top-down and bottom-up actions. A first step to improving products, services and controlling the quality of processes according to the sustainability concept can be the use of reference modelling (Wolniak, Grebski, 2023; Dabees et al., 2023). The task of reference models is to create structural and methodological framework representing a complex prodfucation reality. Reference models define the information structures of a company, represent organisational knowledge, set the standards for modelling and clearly define the space dedicated to controlling the correctness of actions taken (Klimecka-Tatar et al., 2021; Gajdzik, 2016). One example of reference models is the Supply Chain Operations Reference (SCOR) model. The overarching goal of developing the model, was to create a tool that would allow the execution of a supply chain analysis to identify the activities and processes occurring within it and to improve physical and information flows (Zhou et al., 2011).

The standardisation of the description of the relations occurring between individual processes and links in the supply chain enables the development of a system of metrics that allows not only the assessment of efficiency, but also supports adequate decision-making leading to its improvement (Ulewicz et al., 2014; Czerwińska et al., 2025). Measurement and evaluation of individual links and process execution in the SCOR model is possible through the use of appropriately selected key performance indicators (KPIs) (Li et al., 2011; Kottala, Herbert, 2020). The aim of this study was to modify the classical SCOR model to include a key area for manufacturing companies (quality control) and to propose a hierarchical set of key performance indicators designed to measure the implementation of selected processes in line with sustainability. The aim of extending the SCOR model was also to imply the premises of the concept of sustainability by considering its application to the idea of the circular economy on the ground of manufacturing enterprises. The implication of an adequate set of KPIs will contribute to the implementation of a management system based on the monitoring of performance measures, which will significantly facilitate the flexible alignment of short-term objectives of manufacturing enterprises with market requirements in line with the rationale of sustainable development.

2. Application of KPIs in the SCOR reference model

The SCOR model (Supply Chain Operations Reference Model) is an international reference model developed by the Supply Chain Council. The main objective of creating the model was to create a tool that would allow for a comprehensive analysis of the supply chain in terms of detailing the activities and processes involved, as well as improving information and physical flows (Rotaru et al., 2014; Li et al., 2011). The model was based on key supply chain processes which included (Ayyildiz, Gumu, 2021; Saen, Izadikhan, 2024):

- plan, which refers to supply and demand as determined by overall plans that take into account the management of resources and the building of the companies' operational capacities in the long term;
- source, which is the purchase of materials according to a procurement system that includes the verification of suppliers and negotiation;
- make, concerning the realisation of production activities within the framework of the production system and activities which increase the value of the product (creation of added value);
- delivery, concerning all stages from the receipt of customer orders through the definition of the delivery route to the selection of means of transport, as well as the activities currently carried out within the framework of demand management, storage space, order fulfilment;
- returns, concerning the activities related to the return of defective products (starting with raw materials), as well as the acceptance of products that do not meet customer requirements for repair or replacement, as well as activities related to the disposal of materials not needed by the purchasers;
- enable, covering advice on how to support other processes.

The dependencies and relationships between the processes described are shown in Figure 1.

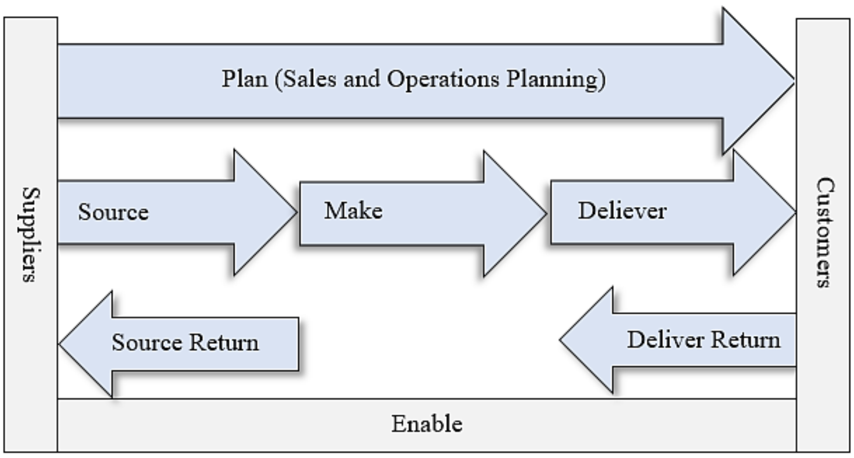

Figure 1. General overview of the SCOR model processes.

Source: Own elaboration based on: (Li et al., 2011; Kottala, Herbert, 2020).

The SCOR model defines dependencies and frameworks that link processes, technologies, metrics and best business practices into a unified structure - a hierarchical, interactive arrangement that is interconnected. The hierarchical structure includes the performance indicator model and process creation (Huang et al., 2005; Webb et al., 2014). One of the key components of the model is the measurement of the results and performance of the various links in the supply chain. The concept of using indicator analysis implies the need for the implication of a balanced approach, indicating that single indicators (including, for example: time, cost) are not adequate to illustrate the achievements of the components of the supply chain. They should be measured and monitored at multiple levels (Georgise et al., 2017; Mazo et al., 2014).

The hierarchical structure of the SCOR model is manifested in the system of measures. The first level takes into account the fundamental evaluation criteria, while subsequent levels can use measures and indicators with greater detail that will fall under the criteria of the first level and at the same time address individual processes in the supply chain (Palma-Mendoza, 2014; Lima, Carpinetti, 2020). Grouped into categories, the indicators from the first level of decomposition include: flexibility, reliability, agility, asset management and cost. Subjecting the indicated characteristics to analysis ensures the comparability of companies, which in a strategic context is defined as a provider of low-cost products to a company that chooses to compete on the basis of ensuring efficiency and reliability (Kocaoglu et al., 2013). Ensuring the hierarchical structure of indicators leads to linking them into meticulously defined sets that relate to different levels of management in a manufacturing enterprise (Aem-on et al., 2024; Khan et al., 2023).

The indicators used within the SCOR model should highlight areas for improvement. The criterion for the selection of an indicator should be the usefulness of the information it provides in relation to the achievement of the stated objectives (Akkawuttiwanich, Yenradee, 2018; Czerwinska et al., 2020). Important within the structure and interpretation of the results is the shift away from local to global optima. Findings based on local metrics can, in the long term, have an adverse impact not only on individual processes but also, on the entire supply chain (Pacana, Czerwinska, 2023; Ahmed et al., 2023).

3. Method

The modified SCOR model solves the problems and limitations of the classic SCOR model. The developed model takes into account the management of the quality control process, capturing it as an integral part of the manufacturing (make) system. The model was extended to include the quality control process. Post-operational inspection is included in the model. This process was included in the model because it is an important area for manufacturing companies. Effective quality control, by ensuring that the final product complies with technical requirements and customer expectations, contributes to minimising the risk of complaints, returns and financial losses. Consequently, an efficient quality control system contributes to a company's competitiveness, increased customer satisfaction and long-term market success. The inclusion of quality control within the analyses carried out using the SCOR model is important because this process is a system without an information feedback loop. Which means that information about irregularities, errors and their causes does not directly reach the employees on the production line. Therefore, such a system cannot self-improve. A diagram of the modified SCOR model is shown in Figure 2.

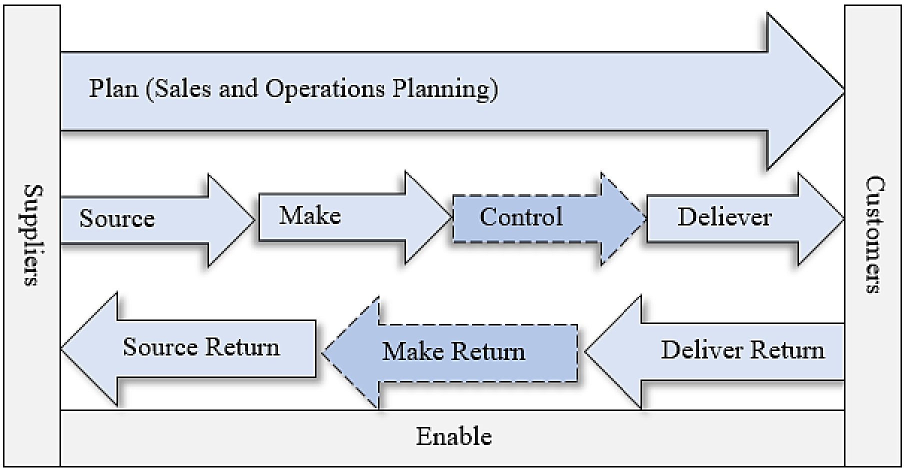

Figure 2. Process approach of the modified SCOR model.

Source: Own elaboration.

The return element of the SCOR model (source return, deliver return) can be seen as a way of performing and fulfilling the demands of the sustainability concept in the execution of environmentally friendly production processes (in line with green manufacturing). The addition of the return make element (Figure 2) makes the SCOR model complete in the context of meeting the sustainability requirements of manufacturing companies. Return make is the implication of the circular economy in manufacturing enterprises, which minimises the use of raw materials and the generation of waste by creating closed loops of processes in which the waste generated is used as a raw material in subsequent production phases.

Implications of the proposed extended SCOR model include:

- creating a model of the current state (‘as is’),
- the use of defined (proposed in the study) performance measures to assess the degree of efficiency of own processes, to compare them with the best ones, to identify priority areas (needing most improvement) and to specify target, expected values of indicators (including desirable, acceptable, warning and unacceptable values),
- implication of SCOR's proposed business practices,
- creation of a target (‘to be’) model.

The integrated processes by in the modified SCOR model should be considered as a whole chain. A comprehensive and unified system translates into a strategy to help companies achieve their goals. There are flows of input materials, labour and information within the production enterprise ensuring the right quantity of products of the right quality and at the right time.

4. Verification of the model

Based on the modified SCOR model, a set of metrics was developed to assess the performance of one of the links in the supply chain - manufacturing enterprises. The metrics were hierarchised based on the structural assumptions of the elements of the SCOR model and developed adequately to one of the main objectives, enterprises in the supply chain - increasing their efficiency. The different levels identified in the schematic illustration of the set of indicators (Figure 3 and Figure 4) correspond to the layers of the SCOR model. The indicators within the first level relate to an element of the model (quality control). Within the second level are metrics that can be adapted to a specific type of process (input, inter-operational, final control). The third level takes into account the metrics corresponding to the main elements of the processes. The links between the metrics indicate dependencies and aggregation in terms of individual process activities.

The developed set of integral indicators allows a detailed analysis of supply chain efficiency in the traditional variant (not including recycling, re-manufacturing and waste use (Figure 3).

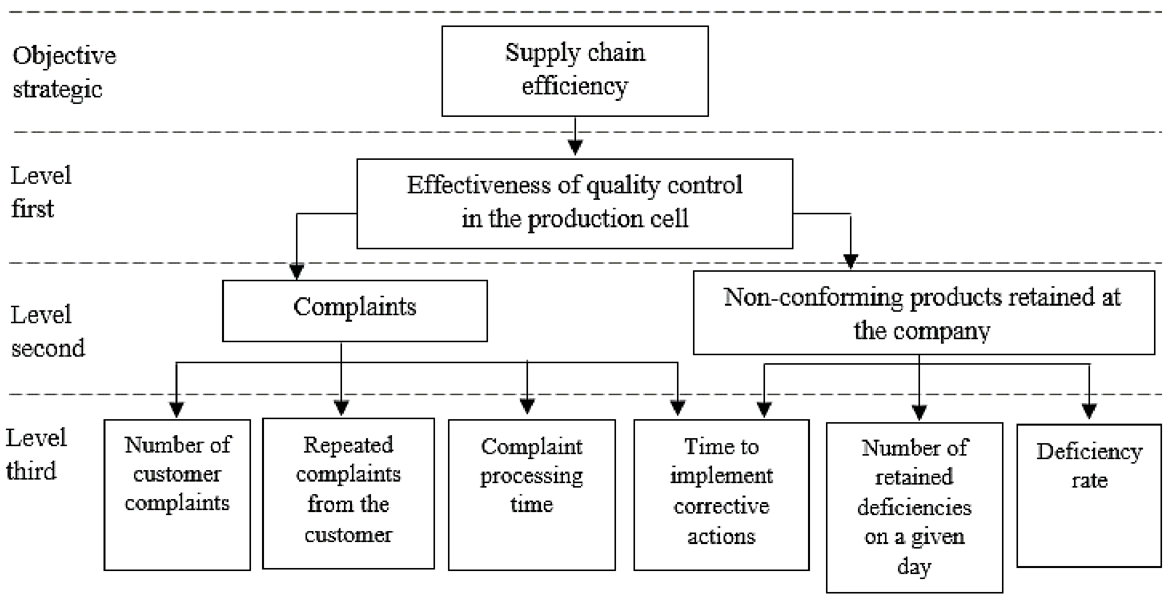

Figure 3. Set of indicators for quality control process (traditional approach - no recycling).
Source: Own elaboration.

A set of indicators aimed at monitoring the level of effectiveness of quality control in production companies that are not oriented towards reverse logistics was developed taking into account the level of external and internal complaints (Figure 3). Within the complaints from customers, the number of complaints, processing time, and recurring complaints were considered, while within the products identified by internal quality control, the number of defects retained on a given day and the defect rate were considered as key metrics. A complementary measure for both levels was the time taken to implement corrective actions.

With reference to the return element of the SCOR model (source return, deliver return), a set of hierarchical indicators was also proposed in a variant including aspects of reverse logistics (Figure 4). The set of indicators is aimed at manufacturing companies capable of implementing and fulfilling the postulates of the sustainability concept in the execution of environmentally friendly production processes (green manufacturing assumptions).

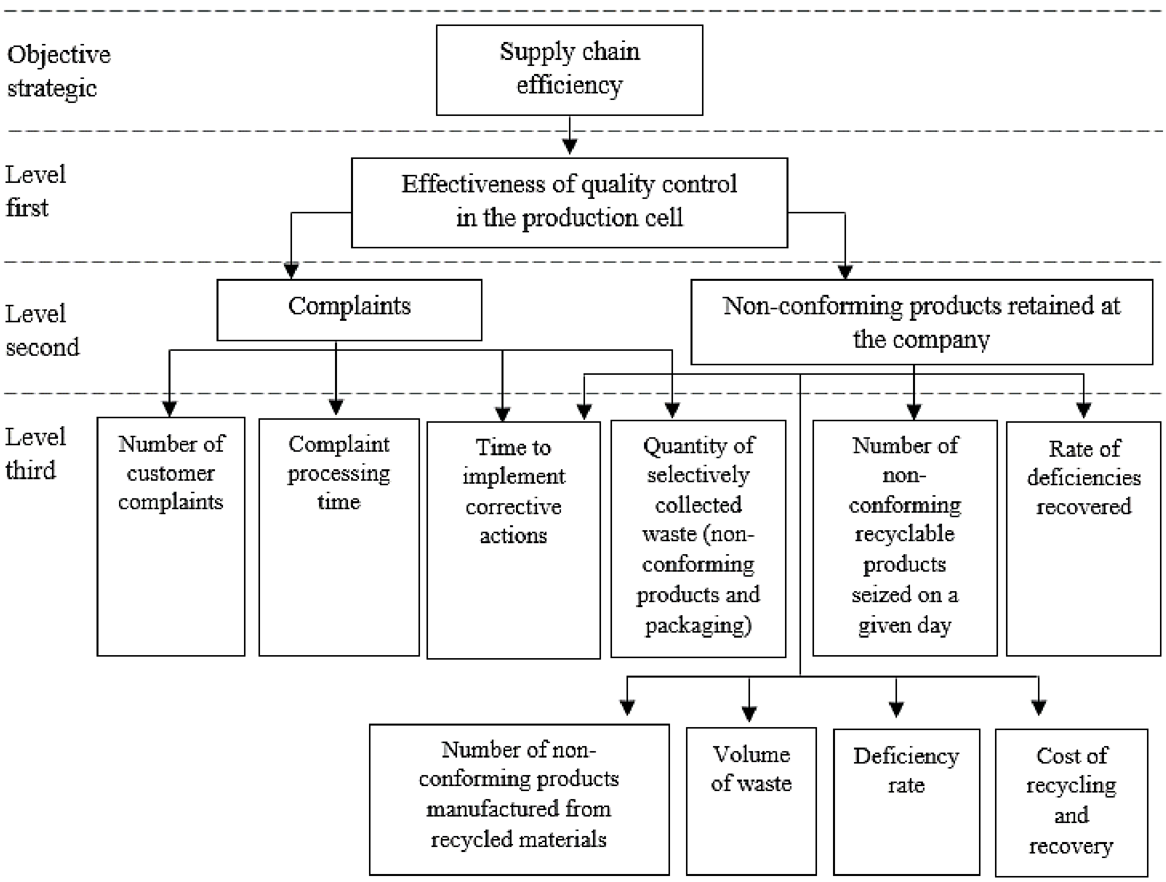

Figure 4. Set of indicators for the quality control process (variancia with feed-back logistics aspects).
Source: Own elaboration.

When monitoring the level of effectiveness of the quality control process within a specific supply chain where recycled or remanufactured raw materials are used, a multi-faceted approach should be taken. Relevant levels include external complaints and non-conforming products identified within the company. The third tier within complaints takes into account the number of complaints, the time taken to process them, while in terms of essential products identified in the quality control process: the rate of deficiencies and the rate of recovered deficiencies, the number of recycled products retained, the volume of waste, the number of non-conforming products produced from recovered materials. The time taken to implement corrective actions and the amount of selectively collected waste were also included in both levels presented. The holistic approach presented for assessing the effectiveness of quality control within the supply chain is important in the context of sustainable development, the foundation of which is a reasonable balance between a variety of factors.

The implementation of the modified SCOR model, together with the proposed set of KPIs, brings tangible benefits within the four main business sectors of manufacturing companies. The first area is control, the next is management in the broad sense, the next is cost savings, which cover the entire product development cycle, and the last segment is quality, which should be a continuous process. Other advantages of the model include:

- integration and provides a cross-industry, universal view of individual supply chain processes,
- ensuring process and functional orientation,
- consistent approach to supply chain improvement,
- the ability to make cross-industry comparisons,
- proposing a coherent set of metrics and indicators with their priorities,
- consideration of multiple areas and dimensions of management.

A limitation of the proposed model is the lack of consideration of important business processes (sales, marketing, product development). The SCOR model lacks a link to the strategy and objectives of the supply chains considered.

5. Summary and conclusion

Providing a comprehensive system of metrics makes it possible to assess the planning processes taking place within the supply chain. This is a basic element that allows further search for savings and efficiency improvements in the flow of products and information. The purpose of the study was to modify the classic SCOR model to include a key area for manufacturing companies (quality control) and to propose a herarchical set of key performance indicators designed to measure the performance of selected processes. The purpose of expanding the SCOR model was also to imply the premises of the concept of sustainable development by considering its application to the idea of circular economy on the ground of manufacturing enterprises.

The developed set of hierarchical indicators and metrics developed with regard to process types (production and quality control in a non-recycling approach and using reverse logistics) allows a detailed analysis of efficiency. The development of two variants of indicator sets allows manufacturing companies to identify the more favorable variant. Implication of a set of indicators aimed at enterprises running processes with reverse logistics in mind will support segmentation of waste materials and their rational reuse. Implication of both models into the production-control environment will help make managers aware of the benefits of applying the concept of sustainability. The idea of implementing indicator analysis based on the expanded SCOR model is based on the elements of a win-win strategy, where the parties are the participants in the supply chain (especially manufacturing companies) and society. Striving to find a solution that takes into account the interests of each link in the supply chain fosters positive relationships based on trust and cooperation.

Further research will be related to the expanded model (detailing the quality control process in accordance with the assumptions of the SCOR model at level two) adequately to the types of quality control occurring in the manufacturing space (input, inter-operational and final quality control). Future work will also be related to the digitalization of indicator analyses in the manufacturing space conducted based on the proposed model

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