TRANSPORT & *LOGISTICS:*
the International Journal
ISSN 2406-1069

Article history:
Received 24th November 2025
Accepted 07th May 2026
Available online 13th May 2026
DOI: 10.46544/TNL.v26n60.03

Article citation info: Trebuňa, P., Kliment, M., Pekarčíková, M., Kronová, J., Hovan, A., Implementation of automation in industrial production and evaluation of its benefits for the enterprise. Transport & Logistics: the International Journal, 2026; Vol. 26, No. 60, ISSN 2406-1069, https://doi.org/10.46544/TNL.v26n60.03

Implementation of automation in industrial production and evaluation of its benefits for the enterprise

Peter Trebuňa**, Marek Kliment, Miriam Pekarčíková, Jana Kronová, Anton Hovan

Technical University of Kosice, Faculty of Mechanical Engineering, Letná 9, 042 00 Košice, Slovakia, e-mail: peter.trebuna@tuke.sk, marek.kliment@tuke.sk, miriam.pekarcikova@tuke.sk, jana.kronova@tuke.sk, anton.hovana@tuke.sk

**Corresponding author: marek.kliment@tuke.sk*

Abstract:

This paper provides a comprehensive examination of the design and implementation of an automated system solution aimed at increasing the efficiency and reliability of production processes in a company focused on manufacturing components for the automotive industry. The main attention is focused on identifying a specific issue within the existing production flow that hinders process continuity, productivity, or workplace safety. Based on this analysis, a technical solution is proposed that incorporates elements of modern automation technologies and production-optimization methods.

The introductory part focuses on a detailed technical analysis of the current state of the production system, describing the function of individual machines, devices, and work operations, as well as their mutual interactions. The aim is to identify critical points of the process that are suitable for automation or reorganization. The findings serve as the foundation for both the conceptual and practical design of the solution, which includes selecting appropriate technical components, integrating them into the existing infrastructure, and defining the necessary adjustments in material flow and work procedures.

The subsequent part of the paper elaborates on the implementation of the proposed system. It includes a description of each stage of realization, configuration of the applied devices, functional testing of the system under real production conditions, and the elimination of potential deficiencies. Significant emphasis is placed on objectively evaluating the benefits — whether in the form of increased productivity, reduced error rates, shorter production times, or improved safety conditions.

The final section addresses the economic analysis of the project, assessing the financial costs of implementation in comparison with the anticipated or achieved outcomes. The result is a comprehensive evaluation of the effectiveness of the proposed automated solution and its importance for the company's future development.

Key words:
Automation, production, optimization, Kuka robot

Introduction

This paper offers an in-depth exploration of the development and practical deployment of an automated system intended to streamline and enhance production activities within a company specializing in automotive component manufacturing. The work concentrates on pinpointing a specific weakness or bottleneck in the current production workflow that negatively affects efficiency, operational continuity, or employee safety. Building on this assessment, the paper proposes a technical solution that leverages modern automation technologies and principles of production optimization to address the identified issue.

The initial sections provide a thorough technical review of the existing production environment. This includes detailed descriptions of the roles and interactions of individual machines, devices, and operational steps, as well as an examination of how these elements jointly influence the overall performance of the manufacturing system. The objective of this analysis is to reveal areas where automation or process restructuring could bring measurable improvements. These insights then form the foundation for the conceptual and practical design of the new system, encompassing the selection of appropriate technological components, their integration into the established production infrastructure, and the definition of necessary modifications to workflows or material handling processes.

Following the design phase, the paper outlines the practical implementation of the proposed automated solution. It documents the entire realization process — from equipment configuration and system setup to performance testing under real production conditions. Special emphasis is placed on identifying and resolving any shortcomings encountered during deployment. The evaluation section subsequently examines the overall impact of the implemented system, focusing on measurable improvements such as increased operational throughput, reduced defect rates, shortened cycle times, or enhanced safety standards.

The concluding part presents a comprehensive economic assessment of the project, comparing the financial investment required for the implementation with the tangible or anticipated benefits achieved. The paper ultimately provides a holistic evaluation of the automated system's effectiveness and its strategic significance for the company's continued growth and technological advancement.

1 Methods and methodology

The company focuses on the production of parts for the automotive industry, particularly components for gearboxes and engine systems, with an emphasis on efficiency and sustainability. The enterprise is designed as a "green foundry," meaning that ecological and energy-efficient processes are prioritized. In addition, the company is actively engaged in innovation and the continuous improvement of its production methods, which enables it to maintain competitiveness in the global market.

The company also places strong emphasis on the professional training and education of its employees. At its plant in Kechnec, it plans to employ up to 160 skilled workers, focusing on training them to operate state-of-the-art machines and technologies. The topic of this contribution itself is oriented toward innovation and process optimization through modernization and automation.

The production process focuses primarily on a fully automated high-pressure die casting system, which ensures a high level of efficiency and flexibility in the manufacture of aluminium components. This process is essential for producing precise and high-quality parts. After casting, the components undergo mechanical machining and assembly, ensuring full responsibility for product quality throughout the entire manufacturing process. This includes quality testing and preparing the parts for subsequent production stages. The company employs several quality-control methods, including leak testing and differential pressure testing. These technologies allow the detection of even the smallest defects and ensure a high level of product reliability (Straka, M. et al., 2020).

The production process consists of the following activities:

- Material reception:
  The purchasing department orders material from the supplier, which is delivered via transport. The material—aluminum ingots—is packaged in steel boxes and transported to the material reception warehouse and the handling zone. From each delivery, a sample is cut using a circular saw for chemical analysis by the quality department. A quality-control worker performs a chemical analysis of the incoming material and compares the results with the supplier's certificate. If the material meets the required standards, it is accepted into the raw-material warehouse for production. The material stock for production must cover at least 48 hours to ensure continuous operation in case of unexpected supplier delays. If material is insufficient, production must be shut down, which disrupts the manufacturing process and results in significant losses for both the company and the customer.
- Aluminum melting**:**
  Internal logistics retrieves the required amount of material from the raw-material warehouse and transports it to the melting furnace. Foundry workers start preheating the furnace to 860 °C, and once this temperature is reached, they gradually load the prepared aluminum ingots into the furnace. Workers regularly inspect the melting process. After the aluminum has melted, they remove unwanted material formed on the surface. The bottom part of the furnace is then opened, releasing the required amount of liquid aluminum into a pre-prepared ladle. A worker transports the ladle to the holding furnace at the machine, where the molten aluminum is poured. The holding furnace maintains the aluminum in a liquid state.
- Aluminum casting:
  The operator starts the machine, which heats up to approximately 300 °C. Once heated, the operator opens the pre-prepared mold chosen according to customer requirements via the control panel. After opening the mold, a release agent is sprayed inside to ensure proper separation of the material from the tool. The operator closes the mold again using the control panel and initiates high-pressure injection of molten aluminum. After the mold is filled, the cooling process begins to ensure the solidification of the product. The mold then opens, and a robotic arm removes the casting. The robotic arm places the casting into a trimming device, where excess small material is removed. The arm then transfers the casting to a cutting unit, where thick sprues are cut off. The casting is placed on a conveyor belt, which moves it to the next phase of the production process. Figure 1 shows the casting molds that are installed into the machine using a gantry crane prior to starting production.

Fig. 1 *Molds for the casting furnace*

- Sandblasting:
  After leaving the conveyor belt, the product is transported to the sandblasting machine. Inside the sandblaster, the product is treated with aluminum beads with a diameter of 1 mm, which removes excess material such as burrs, chips, and other residues. The product then enters a rotating device, where it is rotated 360° to discharge any remaining beads trapped in holes or cavities. The conveyor belt then delivers the finished product, which is picked up by an operator and placed on a wooden pallet for further processing.

Figure 2 shows the sandblasting machine, which consists of three main parts: the conveyor belts, the main blasting chamber, and the filtration chamber with media to prevent dust emissions in the workspace. Sandblasting is the final step in the casting process before the product undergoes mechanical machining. Due to the high noise level, the machine is located in an intermediate storage area. Five workers operate around the sandblasting machine, manually removing any excess material left by the casting process that the machine is unable to eliminate, ensuring smooth and consistent processing of the product.

Fig. 2 *Sandblasting machine*

- Quality Control:
  Every four hours, a quality inspector takes a sample of one product from the sandblasting process for inspection. The selected product undergoes X-ray examination to detect defects from high-pressure casting, such as cracks, cold shuts, and air bubbles. If the product meets the quality requirements, it proceeds to 3D scanning. The quality operator scans the product and compares it with a reference sample. If the product complies with the standards, it is released for mechanical processing. Every manufactured part or production batch must be clearly identifiable. This allows, in case a defect is discovered, all potentially faulty pieces to be traced, determining when and under what conditions they were produced, and analyzing the root cause of the defect. The quality system must ensure this traceability and feedback.

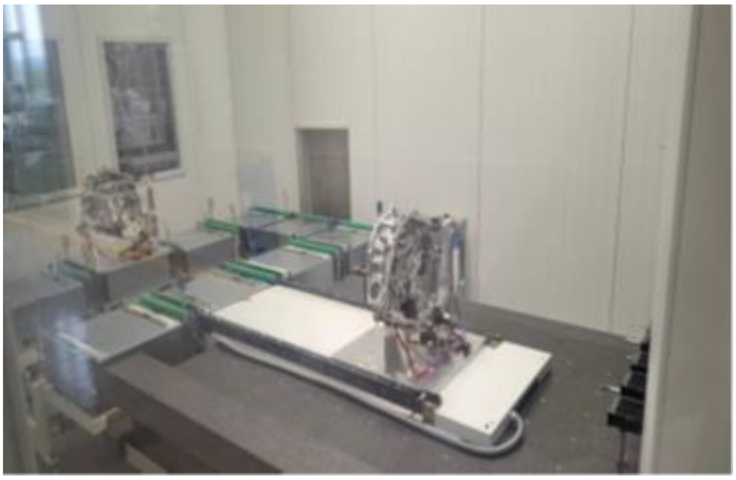

Fig. 3 *Risk analysis when operating equipment in Ergo-Plus software – phase 3*

Figure 3 shows the device used for measuring machined products. Every four hours, a sample enters the measurement station to verify correct machining. If a product fails the inspection, the entire production is halted. If the measured part is found to be defective, the station sends a signal to an operator, who stops the entire production line and notifies the quality department.

- Mechanical Processing:
  Based on the system's request, products are retrieved from the internal warehouse for mechanical processing. The operator first selects the required reference on the production line and then takes a product from the wooden Euro pallet and places it into the fixture on the machine. By pressing a button, the fixture with the casting enters the machine. The next step is marking the product, indicating entry into mechanical processing. A DMC code is then engraved on the product using a laser to ensure full traceability. The machine first mills the surfaces and drills the holes, which are subsequently threaded. A robot picks up the machined product and places it into a cleaning device. Under high pressure, the cleaning device, known as the washer, removes excess burrs and contamination from the machining process.
  Every four hours, one sample is taken for inspection of critical product characteristics using a 3D measuring system. The product then moves to the assembly line, where finished components are installed. Next, the product enters the impregnation station, where micropores are sealed using a special medium. Following this, the product enters a pressure-testing station, where openings are sealed, and air is injected while

monitoring the pressure on a manometer. If the pressure does not drop, the product is sufficiently hermetically sealed and meets customer requirements. At the end of the line, the product undergoes a visual inspection according to customer specifications. The finished part is placed on a pallet in the ordered quantity and labelled with the appropriate tag. The completed pallet is then transported by logistics personnel to the finished goods warehouse. In the warehouse, products are stored while awaiting customer orders for shipment, as illustrated in Figure 4.

Fig. 4 *Finished aluminum products for the customer*

2 Design of the Implementation of a Robotic System into the Production Process

The automation will use a KUKA robot, specifically the KUKA KR 10 R1100-2. This is a robotic manipulator equipped with a gripper that ensures the transfer of parts within the workstation. The robot moves parts from the cart to the engraving nest, then to the inspection position at the DMC code reader, and afterwards either back to the cart (if the code is OK) or to the slide for NOK parts. When the emergency stop is activated, the robot's safety function "External Emergency Stop" is triggered. Opening the safety doors activates the "Operator Safety" function. The robot supports a manual mode T1 for trajectory adjustments and testing, as well as an automatic mode EXT for normal operation.

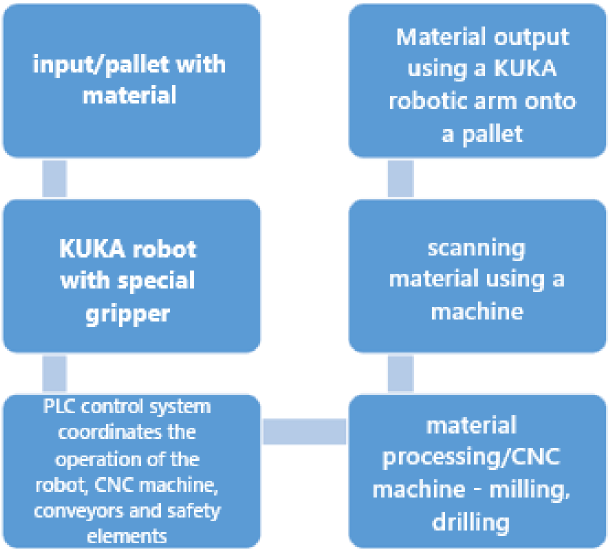

Fig. 5 *Work cycle diagram using a KUKA robot arm*

The KUKA robot or robotic arm can provide us with (Knapcikova, L. et al., 2020):

- The robot's movements are programmed to be as fast and smooth as possible, ensuring that the total handling time is shorter than or equal to the CNC machining time, thereby maximizing machine utilization.
- Continuous exchange of signals between the robot, PLC, and CNC machine is essential for synchronization and safety.
- The system must ensure that the robot cannot enter the machine during machining, and the machine cannot start a cycle while the robot is in its workspace or the doors are not securely closed.

Figure 6 shows the proposed type of robotic arm, which will serve the function of automatic product loading. It is a multi-axis robot with more than three rotary joints. These joints allow it to perform complex movements and reach hard-to-access areas with fewer axes. Each additional axis enables the robot to rotate and tilt in various directions, allowing it to better adapt to the workspace and navigate around obstacles.

Fig. 6 *Robotic arm*

Although the KUKA robot only transfers castings, it plays a crucial role in the entire production chain, where structural quality is essential. The robot's precise handling helps prevent damage to the casting—which could affect its structure or integrity, such as causing cracks—during transfer between processing steps. In some automated production lines, robots can even be integrated with inspection systems that, based on visual checks or other sensors, detect obvious surface defects related to the macrostructure (e.g., large shrinkage cavities) and remove defective parts.

3 Conclusions

The final evaluation compares the capabilities of humans and robots, highlighting their advantages and disadvantages in performing tasks within the production process.

Tab. 1 *Comparison of the advantages and disadvantages of robots and human factors in the production process*

Criterion	KUKA Robot	Human
Speed	Very high for repetitive, precisely defined tasks.	Lower speed for monotonous tasks.
Accuracy and Repeatability	Extremely high accuracy (often to tenths or hundredths of a millimeter), almost perfect repeatability of movements.	Lower accuracy and repeatability, affected by fatigue, concentration, and human factors.
Endurance and Working Hours	Can work continuously 24/7 without breaks.	Requires regular breaks, rest, and sleep; limited working hours.
Strength and Load Capacity	Can handle very heavy loads (hundreds to thousands of kg) effortlessly and without risk of injury.	Limited physical strength; risk of injury when lifting heavy or improperly handled loads.
Work in Hazardous Environments	Ideal for working in environments dangerous to humans (high/low temperatures, toxic fumes, dust, radiation, noise).	Requires safe, clean, and ergonomic environments; in hazardous conditions, expensive and restrictive personal protective equipment (PPE) is needed.
Consistency of Quality	Performs tasks consistently, leading to stable and predictable product/process quality.	Work quality may fluctuate due to fatigue, inattention, mood, or health.
Fatigue and Errors	Does not experience fatigue, emotions, or loss of concentration; error rate is minimal if properly programmed and maintained.	Susceptible to fatigue, which reduces performance and accuracy and increases the likelihood of errors.
Operational Costs	After a high initial investment, has lower operational costs (electricity, maintenance, no wages, benefits, or taxes).	Requires regular wages, taxes, training, benefits, and costs for ensuring proper working conditions.
Flexibility and Adaptability	Low flexibility for unexpected changes or new tasks; requires stopping and reprogramming.	High flexibility; can quickly adapt to new situations, tasks, and process changes.
Problem-Solving and Decision-Making	Can only execute programmed sequences; lacks the ability for creative problem-solving, learning from experience, or complex decision-making.	Capable of learning, solving unexpected problems, improvising, and making complex decisions based on incomplete information.

Acknowledgement

This article was supported by the grant project APVV-17-0258 "Digital engineering elements application in innovation and optimization of production flows", APVV-19-0418 "Intelligent solutions to enhance business innovation capability in the process of transforming *them into smart businesses", VEGA 1/0508/22 „Innovative and digital technologies in manufacturing and logistics processes and system“, VEGA 1/0383/25 "Optimizing the activities of manufacturing enterprises and their digitization using advanced virtual means and tools", KEGA 020TUKE-4/2023 "Systematic development of the competence profile of students of industrial and digital engineering in the process of higher education", KEGA 003TUKE-4/2024 "In-novation of the profile of industrial engineering graduates in the context of required knowledge and specific capabilities for research and implementation of intelligent systems of the future“.*

References

Trebuňa, P., 2017. *Application of Selected Modelling and Simulation Methods in Industrial Engineering;* Technical University of Košice, Faculty of Mechanical Engineering: Košice, Slovakia, ISBN 978-80-553-2835-5.

Saderova, J., Ondov, M., Kovac, J., Szucs, M. and Betus, M., 2022. Simulation of material flow using vertical transport by a double-action mine hoist, *Acta Simulatio*, 8(4), pp.47-50, https://doi:10.22306/asim.v8i4.91

Trebuňa, P., Mizerák, M., Trojan, J. and Kliment, M., 2020. *Digitalization of Manufacturing Processes and Systems*, Technical University of Košice: Košice, Slovakia.

Makysova, H., Galgoci, F., Gyurak Babelova, Z. and Starecek, A. 2024. The improvement of the production process performance through material flow and storage efficiency increases serial production, *Acta Logistica*, 11(1), pp.57-65, https://doi.org/10.22306/al.v11i1.449

Takala, E.P., Pehkonen, I., Forsman, M., Hansson, G.Å., Mathiassen, S.E., Neumann, W.P. and Winkel, J., 2009. Systematic evaluation of observational methods assessing biomechanical exposures at work. *Scand. J. Work Environ. Health*, 47(5), pp.329–347.

Marasova, D., Saderova, J., and Ambrisko, Ľ., 2020. Simulation of the use of the material handling equipment in the operation process. *Open Engineering*, 10(1), pp.216–222. https://doi.org/10.1515/eng-2020-0015

Knapcikova, L., Behunova, A. and Behun, M., 2020. Using a discrete event simulation as an effective method applied in the production of recycled material. *Adv. Prod. Eng. Manag.*, 15, pp.431–440.

Grznar, P., Gregor, M., Krajcovic, M., Mozol, S., Schickerle, M., Vavrik, V., Durica, L., Marschall, M. and Bielik, T., 2020. Modeling and simulation of processes in a factory of future. *Applied Sciences*, 10(13), 4503. https://doi.org/10.3390/app10134503

Straka, M., Khouri, S., Lenort, R. and Besta, P., 2020. Improvement of logistics in manufacturing system by the use of simulation modelling: A real industrial case study. *Advances in Production Engineering & Management*, 15(1), pp.18–30. https://doi.org/10.14743/apem2020.1.346