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Quality Control Process Decision Support System Design in Automotive Supply Industry

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Abstract : Delays in error detection in the quality control process cause wasted materials and human resources, which are very valuable for the automotive supply industry. Thanks to the Decision Support System (DSS) designed within the scope of this work, it will be possible to take the decision to stop production due to the detected errors much faster and the development of error-free human functions. The novel system will be useful to support decision-makers in the automotive supply industry. The decision made during the quality control process will be developed with the support of artificial intelligence and machine learning. The related study is aimed to develop such software to monitor and report the measurement processes of the parts produced on the machining benches, which will be commercialized in the future. As a result, advanced quality and process control, high efficiency, full traceability, minimum error, and taking measures to prevent the repetition of errors with artificial intelligence support, integration between the software used, and high reporting functionality are targeted.

IndexTerms **- Decision support system, quality control, failure prevention, machine learning, industrial monitoring.**

I. INTRODUCTION

In the production process, Quality Management (QM) plays an important role in maintaining customer satisfaction and meeting their requirements [1]. It should include the determination of quality planning, quality control, quality improvement, and other aspects of the quality concept. Also, it enables the detection of errors and improved decision making, but with delay in the execution of corrective actions [2]. Therefore, novel methods should be considered for production to manage the quality in real-time. Nowadays, Industry 4.0 technologies (e.g., the Internet of Things (IoT), Big Data, Cloud Computing, Visual Inspection, Machine Learning) have developed leading advantages in production efficiency, product quality, and cost reduction [3] [4].

Also, the contemporary quality management systems in the automotive industry are discussed in many works of literature. The automotive industry forms a main pillar of the global economy and is one of the current profitable and feasible industries [5]. On the other hand, the automotive supply industry to manufacture goods that are used in the production process of an automobile or part of an automobile takes an important role in the global economy's success. So, constant changes in the industrial economy make the duty of the manufacturers to guarantee high-quality products following the preferences of the buyers. Production companies take actions, enabling identification of possible non-conformities in products and preventive actions, which prevent the occurrence of errors in the future.

Another factor for achieving the global economy's successes in industrial production is to develop the Decision Support System (DSS) as a powerful part of the supply chain. It has been widely used in many applications to support decision-makers, assist, and improve their decisions in related business activities according to selecting the best set of options to increase efficiency, profit, and customer satisfaction regarding the product [6]. Therefore, currently, the decision-makers utilize automation and technological tools such as Information Systems, Artificial Intelligence, Machine Learning, and Data Analytics Software in most of their business activities to make the best decisions in their DSSs.

Recent technological developments cause the generation of an enormous amount of raw data every day in the production sector. For this reason, Machine Learning (ML) studies have become popular because of data availability in great sizes and increasing quantity. The ML is considered as a method of data analysis that can improve automatically through experience. Being a subdivision of Artificial Intelligence, it can learn from data, identify patterns and make decisions with minimal human intervention. The ML application started to be used in manufacturing more than 20 years ago. Some manufacturing tasks

utilizing ML algorithms are Intelligence Systems to support effective decision making, programs to schedule simultaneous production lines, arrangements for maintenance machines, failure prediction, the energy consumption estimation of machines, product quality assessment, and defect detection in manufacturing [7].

Nowadays elimination of inefficient ways of working is one of the most important challenge in automotive supply industries to improve the production factors continuously. It is supposed that the quality of final products delivered to customers with the zero level of error principle is vital in the manufacturing process leading to achieving higher customer satisfaction and loyalty levels. It may be the case that some of purchased products are returned by customers on occasions. Also, we can point to the traceability of the production process as another important factor that the lack of it leads to the waste from overproduction, defects, waiting times, and other unpredicted costs as it is mentioned before. In addition, the production efficiency to utilize resources, minimize waste, and reach higher revenues by using the same assets is another challenge for the automotive supply industry. Moreover, manual analysis of reports by employees as a part of a traditional production process can increase the response time and human error rates. Therefore, implementing an automation system by cross-software integration to analyze reports generated from the quality control process can reduce these factors to an acceptable level and monitor the quality control queue based on priorities.

For the reasons mentioned above, we proposed a novel method in this study to design a Decision Support System for the quality control process in Automotive Supply Industry. As one of the most critical aspects of a production operation is quality management, the primary goal of this work is basically to ensure that the manually executed quality control measurement and reporting processes are traceable with the software to be created. The process will start with the operator entering the information about the product to be sent to the quality control system and will be completed when the product leaves the quality control laboratory and transmits the measurement reports to the relevant supervisors. With the support of artificial intelligence and machine learning, the decision made at the end of the quality control process will be developed, and decision support will be provided with a rule-based system until there is enough data to complete the model. As a result of the study, advanced quality and process control, high efficiency, full traceability, minimum error, and taking measures to prevent the repetition of errors with artificial intelligence support, integration between the software used, and high reporting functionality are targeted.

II. Literature Survey

To increase production quality and efficiency, two important aspects must be supported. The first is to detect and eliminate the expected defects in machine tools beforehand, and the second is to establish a supply network with remote monitoring and maintenance methods when a malfunction occurs [8]. According to Lehto [9], the perspective of human decision-making in different situations is important in supply networks and the addressed methods of expert systems can be developed to capture knowledge for a very specific and limited domain of human expertise in DSSs. In late 2018, Bhullar in [10] proposed an Embedded Intelligence term that is extracted from manufacturing equipment to generate related knowledge to improve productivity and decision-support systems by a multifaceted approach to data collection. Souza et al [11] made an effort to survey decision-making based on system reliability in the context of Industry 4.0 and investigated several technologies to improve the availability of equipment. Also, it is considered that local decisions are no longer sufficient in the current manufacturing industry and the analysis of the organization as a whole is necessary. Thus, it has significant weight in the decision-making process to support different types of strategic decisions in the context of Industry 4.0. As reported by Wuest in [12], using supervised machine learning as a state-of-the-art technology on product state data of the industrial environment is a useful approach to control quality in the manufacturing process. Moreover, Pan in [13] represented an interpretable machine learning method for engineering change management decision support in the automotive industry to have community detection and positive contribution to increasing the quality, efficiency, and transparency of the existing processes. Also, Arena in [14] discussed a novel decision support system for managing predictive maintenance strategies based on machine learning approaches. It extracts knowledge relying on the analysis of a large amount of data from sensor-equipped factories to control industrial systems to increase reliability, efficiency, and detectability of potential failures. In another literature [15], Dutta proposed a conceptual study in perspective of Industry 4.0 adoption in SMEs for quality control process that digitalized related quality practices to address the challenges of shorter time-to-market, flexibility, innovation, etc. As a comprehensive survey [16], Ulengin investigated a decision support methodology to enhance the competitiveness of the Turkish automotive industry and emphasized enhancing the national competitive advantages of the automotive industry by suggesting various scenarios. In [17], Ibrahim proposed multi-objective decision-making methods for optimizing CO2 decisions in the automotive industry, as global CO2 emission is a matter of concern. Therefore, the optimal CO2 management decision is a critical phase in the production process of the automotive industry. As another study related to this challenge [18], the management of wastes produced in the automotive industry has been investigated by the means of decision-making techniques to reach economic, social, environmental, and technical criteria.

The main purpose of this study is to trace the manually executed quality control measurement and reporting processes with the software that we have implemented. The process will start with the operator entering the information about the product to be sent to the quality control system and will be completed when the product leaves the quality control laboratory and the measurement reports have been transferred to the relevant supervisors. With the support of artificial intelligence and machine learning techniques, the decision will be developed at the end of the quality control process.

Firstly, DSS will be provided with the rule-based system until enough data be accumulated through using the software over time. Secondly, the self-learning system will develop its knowledge base to make decisions without the need for a rule-based system, thanks to the analysis of the accumulated data. As a result of the study, advanced quality and process control, high efficiency, full traceability, minimum error, and taking measures to prevent the repetition of errors with artificial intelligence support, integration between the software used, and high reporting functionality are targeted.

III. Problem Definition

In the literature, patent, utility model, and market research conducted during the project preparation studies, it has been observed that similar systems only focus on production tracking, part tracking, and such a system is not used for quality control

purposes. As we know, the main purpose of the quality control is determining any needs for corrective actions in the manufacturing process to help companies meet consumer demands for better products. Also, its related benefits are encouraging quality consciousness, satisfaction of consumers, reduction in production costs, effective utilization of resources, and reduction in inspection costs. However, the current quality control process monitoring in the industry is carried out manually in many companies, therefore, their traceability during the process and retrospectively is reflected as a waste of time and workforce.

IV. METHODOLOGY

In order to solve the mentioned problems, the main innovation of the project is to ensure traceability in the quality control process of the automotive supply industry. Traceability as an essential factor of industries is the ability to trace all processes from procurement of raw materials to production, consumption and disposal to clarify the product track. On the other hand, considering that the processes are carried out manually in the current situation, the use of machine learning in the project is another important innovation. Previously mentioned, machine learning is the capability of a machine to imitate intelligent human behavior and performs complex tasks in a way that is similar to how humans solve problems.

Therefore, the quality control of the products is evaluated by provided machine learning and in the next step, a certain error rating is made. Then, it will be sent to the inspector, and if there is not enough data, decision support will be provided with our developed rule-based system. The decision support system as an information system is used to efficiently improve speed of organizational decision-making activities, facilitates interpersonal communication, encourages learning or training (useful for machine learning), and so helps automate managerial processes. In addition, humans can give computers a set of rules to define the way to process incoming information. There are specific forms of rule-based systems in which the computers assist in the defining of its rules and leading to ruled-based machine learning approaches utilized in this project.

A further innovation of the project is to ensure that the most common quality defects of the system to be developed are stored on a piece-by-piece basis and to provide rapid error detection by examining the historical data of the relevant part in possible cases. These data will be generated by the means of CMMs (Coordinate Measuring Machine) that are found in the measurement laboratories. CMMs measure the geometry of physical objects by sensing discrete points on the surface of the object with different types of probes and these can be manually controlled by an operator or can be computer-based, which the second type is necessary for our system.

As the quality of final products delivered to customers with the zero level of error principle, achieving higher customer satisfaction, and loyalty levels are key factors for automotive industries, our proposed system can cover these needs in its quality control process efficiently. In general, it can be said that the benefits of the system are full traceability, high efficiency, low error repetitions with artificial intelligence support, high reporting functionality, reduced repair costs, and increased productivity.

V. COMPARISON

In this part, we want to compare the proposed method with some of other previously presented methods in the industry as well as the traditional process of the current system and the resulting improvements in terms of productivity and in this regard, reduced error detection time, the return rate of manufactured parts, and decision time. In [19], Montgomery presented a timeline of some important milestones in the evolutionary process of quality control. Also in [20], Godina improved the quality of the automotive industry through Statistical Process Control (SPC). The main objective of this research is to demonstrate how the SPC can assist not only in quality control but also in management decision making and reducing waste in a case study. Moreover in [21], several methodologies for Decision Support Systems have been reviewed by Zarte in different case studies based on the application areas of energy planning, production planning, supply chain management, agricultural sector, and economic and environmental planning and assessment.

On the other hand, our current system previously had the following production process that will be discussed to make a comprehensive compression with the novel presented method. Firstly, the reporting analyses of a high number of various parts were carried out manually which is time-consuming. These reports created after the measurement of the parts from the measuring benches consist of a couple of pages, and it takes some time to find the dimensions that the parts are inaccurate or out of tolerance leading to stopping the production of these defective parts and therefore encountered with production errors because of ineffective time management. Also, the lack of traceability is another challenge of the past system which caused slow decision making, slow troubleshooting, poor business process, and weak sustainability.

As the innovation of this project, highlighting the out-of-tolerance measurements to speed up the quality control process and marking the defective parts visually on measurement reports together with the specification of the defective parts, lead to reducing the time spent on finding the faulty parts in an effective way. It means that in the proposed method, faster troubleshooting offers the ability to investigate and troubleshoot issues related to parts or raw materials. Also, the data generated from our system can help the company optimize the business processes such as informing measurement records and giving the users the ability to monitor the quality control process as a timeline of production events.

As another feature of the new system, evaluating the sustainability of products and value chain is considered by ensuring cost-effective manufacture and meeting the demands of consumers. Moreover, due to the fact that the proposed system is always active throughout the day and can be monitored remotely by decision-makers, therefore the physical presence has been omitted for production management. However, it was necessary to be in the production field over the time in the previous system which caused overhead costs, a lack of traceability, lower autonomy, higher office interruptions, and a decrease in productivity and efficiency because of slow organizational communications to inform the production problems in the decision-making process.

To sum up, the most important components of the project are making the production process of an organization automating the quality control, minimizing human-induced delays, and predicting possible machine downtimes. In addition, traceability of the process will help to detect errors occurring during manufacturing much earlier and to produce fewer faulty parts.

VI. IMPLEMENTATION

The related study is aimed to develop software to monitor and report the measurement process of the parts produced on the machining benches of a manufacturing company operating in the machining industry. This software will report to the determined supervisors by associating the operator who produces the part, the quality control personnel who performs the measurement, the product identity, production date, production location, part measurement file, and from the moment the operator determines the product to go to quality-control process and any errors of faulty machines are reported to the supervisors. Therefore, these are added to a blacklist for frequent occurrence in the control process via the machine learning system for evaluation. After a certain number of logged faults, it will be reported to the decision-makers and as a result, necessary measures are taken to reduce the possibility of producing defective parts by preventing the consequences of such malfunctions.

From a technical perspective, Model View Controller (MVC) as a multi-layer architecture is used in the implementation of the quality monitoring system to develop a platform-independent software with .Net core technology. MVC is a pattern in software design commonly used to implement user interfaces, data, and controlling logic. Also, it emphasizes the separation between the software's business logic and display. Such an architecture provides different financial options by enabling the program to work in different operating systems (e.g. Windows, Linux, etc.). For the database management system, Postgresql is used. Then, in big data analysis and artificial intelligence applications, data analysis libraries of the python programming language (e.g. TensorFlow, Keras, PyTorch, etc.) are used and so learning times reach acceptable levels.

On the other hand, the requirements analysis report is prepared by the IEEE 830 standard, and the software models are made by using Unified Modeling Language (UML) in the design part. Also, Visual Studio as the software development environment is utilized with C# and .Net Core programming language. In addition, other software development tools such as RESTful API, GanttChart, MSProject Plan, JIRA, Bitbucket, Google Drive, and Scrum are used in this project.

Fig.1 is a scheme that resumes the framework of the proposed method. In brief, in the beginning, there is the production phase based on the bench and operator selection. A second phase is related to the quality control process which is necessary to deliver high-quality parts. Further, there are reporting phase in which CMM machines generate reports, and these reports are stored in the database for machine learning purposes. The last part is about the decision-making process to continue or halt the production cycle.

VII. CONCLUSION

The main aim of this work is to give a framework that is applicable to the Decision Support System of quality control process by the means of Machine Learning concepts in the production cycle. Particularly, this method is applicable to stop production due to the detected errors in the automotive supply industry. The other aims which follow this work are monitoring the business process, increasing efficiency, minimizing and preventing the repetition of errors with artificial intelligence support, and high reporting functionality.

VIII. FUTURE SCOPE

As the noise level is quite high in the production areas of the manufacturing companies and the operators are sometimes far apart from each other in the machining sector, another innovative aspect of this project can be considered to develop a cost-effective IoT device such as armband type equipment. It can notify the operators of the measurement completion information through vibration by the means of wireless technologies in integration with the proposed system. Thus, notifications from the related supervisors will be transmitted to the relevant operators as an alarm to ensure that the operators make appropriate decisions based on the given guidelines as quickly as possible.

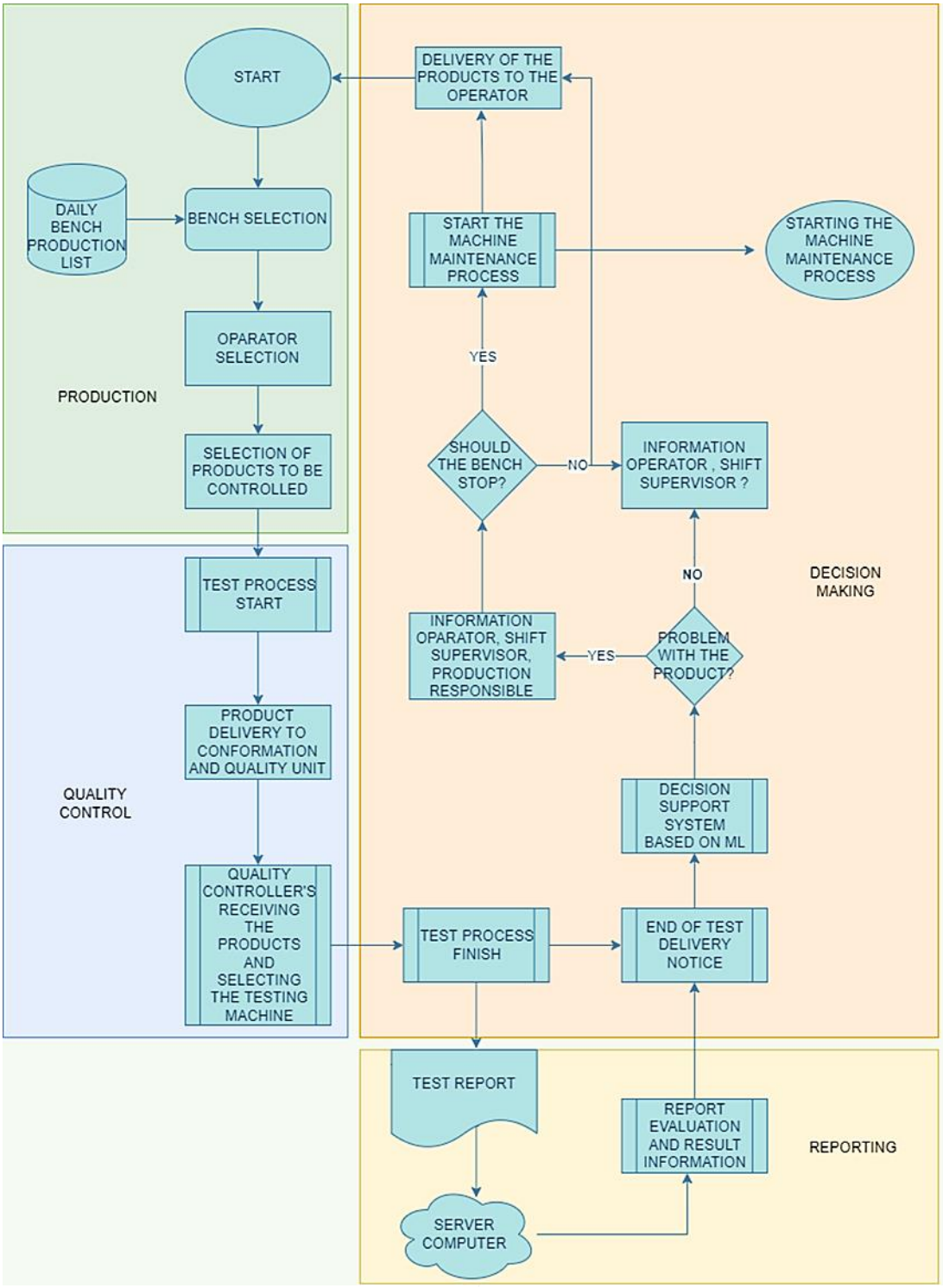

Figure 1 The framework of the proposed method

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