THE FUTURE OF AUTOMOTIVE QUALITY CONTROL: HOW CLOUD-BASED REPORTING IS CHANGING THE GAME

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Abstract:
The automotive industry faces challenges in maintaining quality control while at the same time reducing costs and improving efficiency. Outsourcing has emerged as a potential solution. Such an approach can create issues such as communication barriers, quality control problems, and limited visibility into the manufacturing process. This study proposes a cloud-based quality reporting solution to overcome these challenges by providing real-time data analytics, facilitating proper communication, and enabling visibility into quality control processes. This solution significantly reduces waiting times for information regarding product quality status and allows interested parties to access data immediately. The outsourcing company, product producer and customer receive flexible, traceable, mobile cloud-based analytics in real-time. Challenges of this solution are the need to secure data, manage access and ensure the appropriate quality of data by persons performing control. The paper provides practical recommendations for implementing cloud-based quality reporting systems.

Key words: automotive industry, cloud-based reporting, control, outsourcing, real-time data analytics

INTRODUCTION

The automotive industry faces ongoing pressure to improve production efficiency while maintaining high-quality standards. Global competition and the demand for cost-efficient production methods are characteristics of the automotive industry. Outsourcing has become a common practice in the industry to reduce costs, increase efficiency, and improve supply chain management [1, 2]. Outsourcing quality control is one approach that has emerged to address these challenges. However, outsourcing quality control brings new challenges, including communication barriers, quality control issues, and limited visibility into the manufacturing process. This approach also poses risks, particularly in quality control. Quality control is essential in ensuring that automotive products meet the desired standards and specifications [3]. In this article, we explore the potential benefits and challenges of using cloud technologies in quality reporting for outsourced quality control in the automotive industry. Cloud-based quality reporting presents a novel approach to outsourced quality control by providing real-time data analytics, facilitating proper communication, and enabling visibility into the quality control processes for all stakeholders involved, including the outsourcing company, the manufacturer, and the final recipient. We review existing literature, provide case studies, and offer practical recommendations for implementing cloud-based quality reporting systems. This article will be valuable to automotive industry professionals and researchers interested in improving outsourced quality control processes.

This paper proposes a novel approach that combines cloud-based quality reporting with outsourced quality control to address these challenges. The article examines the benefits of this approach, such as improved accuracy, increased visibility, and reduced costs [4]. The paper includes a comprehensive literature review of existing studies on outsourcing, cloud technologies, and quality reporting, along with a case study analysis of cloud-based quality reporting in the automotive industry. Modern production models following the principles of Industry 4.0 include operations on the data. Using information properly is an important factor essential to competitive differentiation. If that could be big data it gives additional possibilities to match stakeholders' expectations [5]. Proper data management could have a possible impact on the scrap level and also support production efficiency [6]. Providing real-time data for analytics from outsourcing partners allows for reducing inconveniences caused by the nature of external cooperation. The constant data flow also allows proper communication and fulfilment of the partnership

reporting standard. Deciding if quality control processes shall be outsourced may depend on the ability to visible reporting data in real-time [7]. The novelty of this approach is that all stakeholders involved in the process have access to the data in real-time, enabling better communication and transparency. Practical recommendations for implementing cloud-based quality reporting systems are also provided.

BACKGROUND AND CONTEXT

The situation in the European automotive market in the third decade of the 21st century became complicated. COVID-19, Russian aggression in Ukraine, and inflation happened within a few years. It has caused shortages of components, branch consolidation and some suppliers' bankruptcy. Meanwhile, we are witnessing a change in politics connected with the "FIT for 55", trials of banning production combustion engine cars until 2035 [8] development of electronic and autonomous vehicles. It causes the automotive branch challenge to find itself in a VUCA world (volatility, uncertainty, complexity and ambiguity) – that acronym was invented in the US army as a shortcut for describing situations on the battlefield. It also became a term used in academic writing to present complicated times [9]. That all pushes automotive producers to use outsourcing which allows for mitigating risk connected with overdeveloped internal structures in changing conditions. One of that processes may be quality control. The article includes a literature review. The review applies to existing studies on outsourcing to show current trends, reasons and challenges connected with this solution. The study also provides an overview of cloud technologies and big data solutions, which could enhance the efficiency of external partnerships. Quality reporting is the next point of review. The paper analyses the influence of proper reporting on internal production processes in the automotive industry. The article has included a case study of cloud-based quality reporting in the automotive industry. Presentation of examples shall simplify the idea of solution application. The case study presentation allows us to identify and indicate the benefits and challenges of that solution. The paper also contains recommendations for implementing cloud-based quality reporting systems.

PURPOSE OF THE ARTICLE

There is a practical problem in the automotive branch connected with real-time reporting. The solution could be the use of cloud reporting. The paper identified implementation barriers to such solutions based on the case study. Additional strongness and weaknesses analysis is included. All interested stakeholders can benefit from real-time quality reporting: suppliers, customers and third parties. The experiences of companies from the automotive industry indicate the necessity of enhancing quality reporting systems. Welcomes are sharing solutions allowing access to data in real-time based on cloud solutions. Nowadays the weight market isn't filled by such type of solutions. It creates an opportunity for further development for scientists and entities from the automotive industry.

LITERATURE REVIEW

Outsourcing quality control can result in communication barriers, quality control issues, and a lack of visibility into the manufacturing process. These challenges can be addressed through cloud-based quality reporting, which offers real-time data analytics, real-time communication, and visibility into quality control processes. Often outsourcing is a result of a decision "make or buy" [10]. Outsourcing can be used as well for production and services. The reason for using outsourcing is the fact that companies can focus on their processes and reduce operational costs [11]. It allows companies to improve their business units and increase efficiency [12]. Partnership with external companies for production and services allows them to share outsourcers' know-how and technologies. Outsourcers are focused on their processes which can lead them to innovation in their field. By working with many customers in the same way, outsourcing companies can use best practices from each partnership and develop their internal working models [13]. Cooperation with outsourcers should be based on a holistic approach. Outsourcing shall be characterized values as technical skills, the total cost for a process/service, involvement of the customer, core business closeness, safety, reservedness, easiness to monitoring outsourcer, performance, and internal human resources [4]. Moreover, an important factor is to communicate the effects [14]. Real-time cloud-based reporting of outsourcing results could be a focal point in automotive quality control outsourcing allowing to meet branch expectations. Outsourcing in the automotive industry has happened for decades. It refers to products and services.

Production outsourcing is well described in the literature concerning supply chains. Precise information about material suppliers is included in technical standards such as VDA or IATF. Those standards also require a structured approach to services. Process simplification by automotive producers pushes them to outsource. Concerning international standards, manufacturers supervise external companies in more and more detail. Cooperation with outsourced shall be well prepared. Clear terms of partnership support avoiding loss of operational control, misunderstanding and wrong management decisions. A sufficient flow of information requires both partners' continuous exchange of information.

Reporting in cyber-physical systems (CPS)

Industry 4.0 requires agility of production and can be supported by intelligent systems, IOT, cloud technologies end embedded control [15]. Cyber-Physical Systems (CPS) popularization in Industry 4.0 allows the combination of internal and external elements in production systems. Datasets obtained make possible Big Data Analytics (BDA). Cloud technologies allow for flexible coordination between agents and support the decision process [16]. The

development of communication technologies in manufacturing is represented by Cyber-Physical Systems, which are collaborating entities connected with the physical world and by ongoing processes that provide and use data [17]. Plenty of possible CPS mentioned are also among others quality control/inspection reporting systems and communication systems [18]. An enhanced system could support quality assurance and provide effective results by using sufficient information and stimulating reliable decisions [19]. The initial contribution of the integration of industry 4.0 with quality management, however, these are not exhaustive data, based on the analysis of the systematic literature review (SLR), 37 case studies of Total Quality Management (TQM) identified in the years 2015-21, only 6 of them are based on case studies [20]. Quality control reporting data are important components of TQM [21]. The outsourcing of the quality in CPS systems allows for better quality control at different stages of production, regardless of geographical location. It enables car producers to use specialised suppliers' expertise and experience in quality control. Fig. 1 shows the outsourcing company's collaboration and reporting scheme.

Fig. 1 Outsourcing company cooperation and quality reporting scheme

However, systems integration, challenges and opportunities resulting from that study compared with the TQM approach require extended research.

Research objectives

By using cloud-based technologies cooperation could be closer than ever used to be. Such solutions, especially in the context of quality control, may support the integration of both – supplier and recipient systems. The visibility of data is a significant factor causing enhance of processes productivity. Well prepared database creates an opportunity for data analytics which is an additional added value of the solution. It supports proper communication between partners and the internal flow of information. The research gap concerning the connection of outsourced quality control reporting is defined based on the literature review. The article aims to answer the questions:

1. Could cloud-based reporting reduce data missing caused by outsourcing quality control processes?

2. How outsourcers' defects reporting could support quality improvements of automotive producers?
3. Does sharing defect details with all stakeholders in real-time could protect production process stability?

Case study in the automotive industry

The case study in the article will be an example of a quality control reporting system prepared by an outsourcing company operating in mass production, especially automotive. The considering model of cooperation is that an outsourcing company control/sort out components on behalf of suppliers if it is required. The company describe their solution as an advanced database where the results of all work carried out for the company's clients are updated. Each partner receives an individual login and password, which allows access to the results of outsourced work remotely, 24 hours a day. Reports could be available just after the completion of the control. The system includes also such elements as ordering, control specification and parties confirmations and traceability monitoring. The system is based on cloud technology and is available via the website as well for computers and mobile devices. There is an option to combine data from the system with part producers systems. The system allows sharing of data with all interested parties connected to the control activities which means producers of parts and their customers - recipients.

The architecture of the system is based on 6 steps (Fig. 1). Starting from placing an order by the customer to an outsourcing company, what happens when a demand occurs. The second point concerns the specification of details for control/sorting activities. 3rd point refers to accepting or confirming by all interested parties the scope of control/sorting. Due to the remote setup of the control, all details confirmation is required. Control starts after confirmation. Point 4th is about reporting and allowing all interested parties access to data analysis. It means that just after parts control data is available in the system and allows further processing. Point 5 concerns all necessary formalities connecting with the closing of control and commercial settlements. The last step mentions access to the dashboard for all users. There they could generate automatic statements and sum up open issues. The novelty of the solution is caused by the constant access to the process for all stakeholders. The exchange of information is possible due to the use of the cloud allows without time waste communication by the parties (Fig. 2). Outsourcing companies can collect all necessary information from the part producer and approval from the recipient of the part before control. After control cloud *solution enables reporting sharing in a real-time manner.*
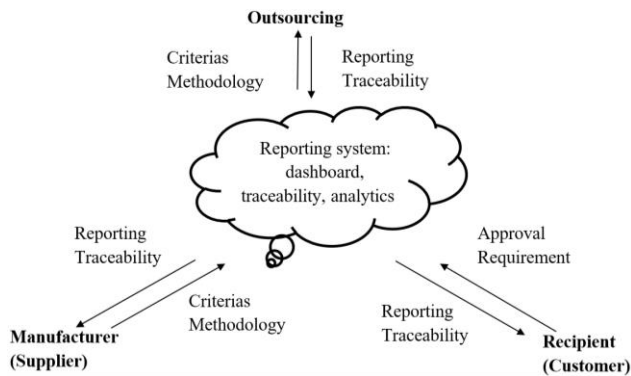
Fig. 2 Stakeholders flow of information

Benefits of this case study

The methods of quality control reporting by in-house employees and the outsourcing company can be different but must include common points such as:

1. Analyzing quality control requirements and selecting tools,
2. Configuration of quality control methods and reporting system,
3. Testing and implementation of methods and reporting,
4. Start quality control and reporting,
5. Monitor quality control results and implement corrective actions if quality problems occur,
6. Optimise quality control processes to improve the efficiency and quality of operations,
7. Continuous improvement of processes and tools to ensure the best results and adapt to the changing needs of the manufacturer.

The differences between the methods of quality control reporting by in-house employees and an outsourcing company usually relate to the accuracy and detail of the report and the time required to perform the quality control and deliver the results. With in-house employees, the quality control report may be more detailed and accurate but may require more time to prepare. In the case of an outsourcing company, the report may be less detailed but will be delivered more quickly, which can be important in high turnover production. Classic quality control reporting by in-house employees relies on traditional methods and tools such as spreadsheets, paper documents and email. In this case, every step in the quality control process is performed by in-house employees and reports are generated and communicated internally. On the other hand, quality control reporting by outsourcing employees using cloud-based solutions relies on modern tools and technologies such as quality management software, online collaboration platforms and cloud computing. In this case, outsourced employees carry out quality inspections on behalf of the manufacturer, and reports are generated and communicated using cloud-based tools.

Challenges faced in this case study

Cybersecurity - the rapid increase of cloud solutions is the tendency of last years. Users consider the cloud environment very safe, often without real images of dangers connected with it [22]. One way of ensuring safety is technical measures. Control policy models, cryptographic protocols, firewalls, better detection, and tools evaluating and assuring can support problem-solving [23]. Storage, access, processing, collection and data analysis are integral elements of the cloud reporting process. Cybersecurity has to face such

problems as malicious attacks, unauthorized intrusions, and more. Cloud computing systems could be affected also by data injections causing integrity and accuracy problems. Solid security solutions for Big Data CPS are required [24]. The total number of information is constantly growing. Correct identification, processing and archiving of data are required for databases due to the many factors such as information, compliance, quality, data protection and intellectual property. Data management is a complex task which software operators must face [25]. Solutions such as 2-factor login, data encryption and proper policy of access and rights and so on are highly recommended or even necessary to have. Another challenge is to provide the proper data on time. It requires a detailed alignment process for all staff engaged in the reporting process in the company. All interested parties should understand the nature of the data such as defect names the same way. It means that descriptions should be possibly universal and clear. When comparing the two approaches, several advantages of outsourcing quality control cloud-based reports can be identified what could be based on the comparison of 2 types of reporting presented in Tabel 1 and Tabel 2.

- High efficiency – cloud-based solutions allow for faster quality control and report generation compared to traditional methods. No additional activity is required, activities are performed automatically in the system.
- Flexibility – cloud-based solutions allow for easy scaling of activities and provide flexibility in case of the need to adapt to changing manufacturer requirements. A change in the scale of operations is always analogous to reporting and does not generate communication barriers.
- Security – cloud-based solutions offer a higher level of data security using modern IT tools to secure systems. Traditional reporting methods do not generate such capabilities. Data security is particularly important for the automotive industry, it is advisable to have confirmation through TISAX or ISO27001 certification.
- Online, shared cooperation – Cloud-based solutions enable outsourcing staff to collaborate easily and quickly with the manufacturer and all stakeholders, increasing efficiency and enabling faster decision-making.
- Tracking results – Cloud-based solutions enable the manufacturer and stakeholders to track quality control results in real-time, allowing them to react to quality issues and take corrective action more quickly.

Table 1
Classic reporting

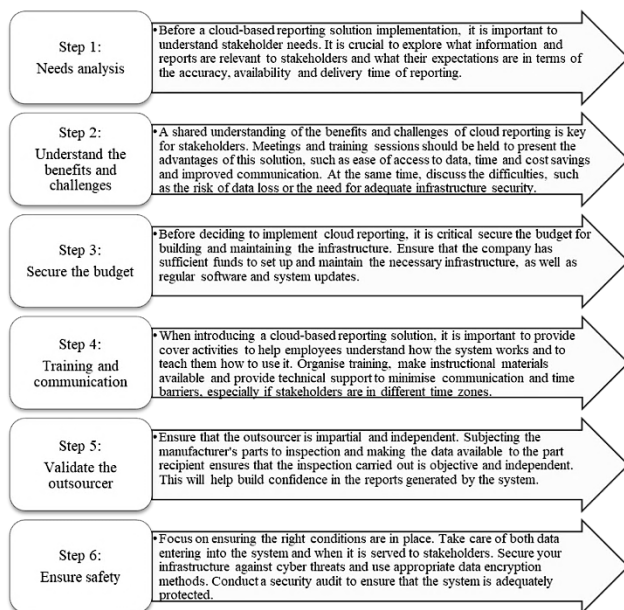| Availability	Costs	Quality	Safety	Flexibility	Integration
The information available to the manufacturer's employees	The need to provide adequate infrastructure	Latency in data processing can slow down the response	The need to provide physical protection for physical documents	The required use of dedicated tools and resources may result in reduced scalability	Methods are usually isolated from other company systems
Reporting requires more time, data arrives slower	Software licenses required, need for updates	Possibility of different versions of reports with bad communication	Providing cyber protection to your server infrastructure	Form sharing is required to present data externally	Manual data entry is required for errors and delays
Availability of inspection results only in the workplace	Required staff training in reporting software	Limited ability to integrate reports into production systems	Proper supervision of accesses, compliance with the GDPR	Limited ability to respond to increases/decreases in demand	Difficulty in integrating with existing systems
Data analysis requires appropriate tools and processing of reports	Secure the flow of paper reports and server infrastructure	The high level of complexity of the solution limits transparency and access to data	Backup requirement, redundancy policy, TISAX, ISO27001		

Table 2
Cloud reporting

Availability	Costs	Quality	Safety	Flexibility	Integration
The information available to all interested parties (clients, external institutions)	Utilization of the service provider's infrastructure	Good data availability can allow you to react faster to defective production	Adequate data protection is required to prevent breaches.	Ability to use and limit external resources when needed	Possibility of system integration with other ERP, CRM or MES types.
Possibility of immediate reporting	Costs included in the price of the service or the form of a subscription	There is only one, up-to-date version of the data available to interested parties	Possibility to use data encryption, access control, and activity monitoring.	Share data in the cloud instantly	Ensuring maintenance-free data flow between systems
Access to control results from anywhere with Internet access	The service provider provides training in-house	Possibility of integration of the reporting system with production systems	User authentication required, 2-factor login, GDPR compliance	Possibility of cooperation between entities that do not require additional actions	Ensuring the appropriate quality of transmitted data through functionalities
Detailed analysis is possible thanks to the tools built into the cloud reporting system	Data security must be ensured: encryption, access control, certificates, etc.	The use of a user-friendly interface enables ease of use	Backup requirement, redundancy policy, TISAX, ISO27001		

In summary, quality control reporting by outsourced employees using cloud-based solutions offers many advantages over classic quality control reporting by in-house employees. It is more efficient, flexible, and secure, enabling easy online collaboration.

Implementation recommendations
In the context of the automotive industry, there is a need for a cloud-based reporting solution for outsourcing quality control. Implementing such a system can benefit both outsourcing companies and customers, however, the complexity of the relationship between the parties and the organisational and technical aspects need to consider. Recommendations are present in Fig. 3.

Step 1: Needs analysis	Before a cloud-based reporting solution implementation, it is important to understand stakeholder needs. It is crucial to explore what information and reports are relevant to stakeholders and what their expectations are in terms of the accuracy, availability and delivery time of reporting.
Step 2: Understand the benefits and challenges	A shared understanding of the benefits and challenges of cloud reporting is key for stakeholders. Meetings and training sessions should be held to present the advantages of this solution, such as ease of access to data, time and cost savings and improved communication. At the same time, discuss the difficulties, such as the risk of data loss or the need for adequate infrastructure security.
Step 3: Secure the budget	Before deciding to implement cloud reporting, it is critical secure the budget for building and maintaining the infrastructure. Ensure that the company has sufficient funds to set up and maintain the necessary infrastructure, as well as regular software and system updates.
Step 4: Training and communication	When introducing a cloud-based reporting solution, it is important to provide cover activities to help employees understand how the system works and to teach them how to use it. Organise training, make instructional materials available and provide technical support to minimise communication and time barriers, especially if stakeholders are in different time zones.
Step 5: Validate the outsourcer	Ensure that the outsourcer is impartial and independent. Subjecting the manufacturer's parts to inspection and making the data available to the part recipient ensures that the inspection carried out is objective and independent. This will help build confidence in the reports generated by the system.
Step 6: Ensure safety	Focus on ensuring the right conditions are in place. Take care of both data entering into the system and when it is served to stakeholders. Secure your infrastructure against cyber threats and use appropriate data encryption methods. Conduct a security audit to ensure that the system is adequately protected.

Fig. 3 Recommendations for implementing

Conclusion, the implementation of cloud-based reporting as outsourced quality control in the automotive industry brings many benefits, such as streamlined processes, better information management, identification of quality issues, better use of analytical data and improved collaboration. Before implementing such a solution, it is important to carry out an analysis of the customer's needs, secure the infrastructure appropriately and provide appropriate training activities for employees. If done correctly, the process will allow for use cases where cloud reporting is more effective than classic reporting.

CONCLUSIONS

The use of cloud-based reporting of quality control results implemented on an outsourced service basis brings several advantages over classic reporting. A comparison of the two models shows that the quality control reporting process is possible to improve. When implemented correctly, it is possible to achieve such benefits as facilitated access to data, cost optimisation, improved reporting and data quality, increased data security, flexibility and database integration capabilities. Improved communication between stakeholders enables more effective decision-making in less time. Direct communication could cause avoid data missing. Being in touch immediately should promote quick feedback that supports constant data review. By using outsourcing, it is possible to reduce the costs associated with having an in-house team and infrastructure. Costs will only be bear for the necessary tasks performed, which also improves scalability. External support could be used only to the extent necessary at any given time, which ensures a flexible approach and optimal use of resources. A modern communication solution such as cloud reporting can significantly improve the flow of information and the speed of response for all stakeholders

in the event of changing audit results. Cloud providers are concerned about data security, including storage, encryption and protection against unauthorized access. However, despite the numerous benefits, is cloud reporting of outsourced quality control results widely used in the automotive industry? The recommendation indicated in the article encourages such solutions with the right organizational assumptions for the implementation of such projects. Immediate access to quality control data should significantly help to react car producers. Improvements in the production process based on fresh data could be easier, better fitted and quicker. Giving a chance for all stakeholders to be aware of quality control progress can also protect production process stability.

Not only reporting, but also storing and processing data in the cloud has significantly advantageous features in the case of large sets of industrial data or their highly intensive processing. Such cases are encountered in distributed computations, which are currently a significant segment of machine learning [27, 28], as well as in real-time monitoring of industrial processes [29]. Similarly high demand for memory resources and computational power arises in the modeling of corrosion processes [30, 31] and chemical reactions [32].

Cloud reporting makes possible predictions of coming trends. It gives the opportunity to plan as well production as the logistic processes. However, the limited occurrence of the solution may be due to a lack of awareness regarding the benefits of outsourcing and cloud solutions. Incomplete knowledge of the solution's strengths or limited confidence in the changes negatively affects the implementation possibilities. Automotive companies have complex processes. Traditional caution and lack of full understanding of the benefits can cause reluctance to implement outsourced cloud reporting systems. Also, concerns about data security, lack of widespread use and incompleteness of vendor solutions limit their use in the automotive industry. It is important to note, however, that this state of affairs may change with the growing awareness of automotive component market participants. On the other hand, the attainment of information security certification by outsourcing companies and the development of applied solutions may have a stimulating effect. The issue could be an area for further research.

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