Material management in automobile industry: Era 4.0

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Abstract. Nowadays, a lot of places worldwide are using Industry 4.0 technology. Smart manufacturing, supply chains, warehousing, logistics, and materials are all developed with the usage of these technologies, especially in automobile sector. It can potentially resolve complex production issues from a commercial perspective. Industry 4.0 technologies that are available for enhancing manufacturing procedures and material quality of automobile industry are thoroughly examined in this article. In the upcoming era of vehicles, we have enumerated the several technologies that are currently available, together with their attributes and advantages for efficient management. Automobile businesses may optimise their inventory and material waste with the use of digital technologies, which lowers costs. When necessary, employees who are located on different sites can work together with ease due to remote collaboration. By helping them stay current with knowledge, these tools eventually close communication barriers. Proper equipment monitoring in industries utilising Industry 4.0 technology will be aided by smart predictive analysis. Early detection and resolution of material defects is possible with the help of these advance technologies. Additionally, this meets the customer's expectations and offers transparency in the systems and procedures.

Keywords: Industry 4.0, Automobile Industry, Artificial Intelligence, Smart Material, Smart Manufacturing, Organization, Material Quality, Material Management, Internet of Things.

1 Introduction

Globally, industry 4.0 technologies are currently being actively utilised. These technologies are very promising and have changed practically every industry, including the automotive one. As stated by a survey released by Markets and Markets, the market share of Industry 4.0 is anticipated to reach USD 150 billion by 2024, having surpassed USD 71.7 billion in 2019 [1]. Now, however, at the start of 2024, it goes beyond that. One result of the COVID-19 pandemic, is there an increase in the adoption rate of this technology, and its market share may even be larger than expected. Given the extensive usage of these cutting-edge technologies, an appropriate management system is required [2, 3]. In contrast to other industries, the automotive sector uses these innovative tools to manage their inventories more effectively and better. This paper concentrates on Industry 4.0 innovations for an effective
management system in the automobile production process. Technologies such as Data Analytics, Cyber Security, Internet of Things (IoT), Artificial Intelligence, Advanced Robotics, Augmented Reality, Cloud Computing, Digital Twins, and Additive Manufacturing (AM) are employed in the sector that produces automobiles. This sector of the economy has seen significant changes on recent days, and further change is anticipated in the days ahead. A suitable management system must to be maintained to oversee the numerous new and developing technologies. These technologies can be fully utilised with the appropriate management systems set up. An industry can enhance the system of manufacturing organisations and material quality management using Industry 4.0, explained by Ammar et al. [4]. The COVID-19 pandemic can be addressed with the use of Industry 4.0 technology, as demonstrated by Javaid et al. [5]. Utilising telemedicine (TM) applications is a great way to combat the COVID-19 pandemic, as highlighted by Bahl et al. [6]. Utilising Industry 4.0 technologies, digital information is improved throughout the COVID-19 pandemic [7-12].

2 Objectives and methodology

Technologies of Industry 4.0 are widely used nowadays. Many of these tools have been adopted by small firms and businesses since the start of the COVID-19 pandemic, especially in automobile industry. Thus, an appropriate management system is necessary for utilising these technologies as efficiently as possible. This paper looks at the key applications of Industry 4.0 technology to raise the effectiveness of automobile industry's manufacturing-based management systems. To get a preliminary idea of the kinds of articles that are available, Google Scholar was initially used. Extensive search terms were first used to generate a list of peer-reviewed, primary source research publications on Google Scholar. To offer a more focused search, we made use of the Emerald, IEEE Xplore, ScienceDirect, and NCBI databases. The following search terms were chosen for this literature analysis: Industry 4.0, Additive Manufacturing, Inventory Theory, Inventory Management, Automobile Industry, Automation, Data Science, Big Data, Predictive Maintenance, Digital Management, Manufacturing Management, Smart Manufacturing, Artificial Intelligence and Internet of Things. To find the most relevant and closely defined articles, these terms were combined in a variety of ways using the 'AND' command. The goal of the literature review, as based on the research queries in the article, had to align with the sources that were evaluated. In addition, we searched for journals that often-published research articles that matched our goal theoretically. Given that Industry 4.0 and Industry 5.0 are rather recent and advanced fields, we also made sure that the journals we used had the most recent publications, no older than 2017. We evaluated the data after taking these things into account.

3 Industry 4.0 in automobile industry

Industry 4.0, commonly referred to as the fourth industrial revolution, made its debut at the 2011 Hannover Messe (Trade Fair) in Germany. Afterwards, it was deemed to be a tactical approach to revolutionize the manufacturing sector [13]. Flexible automation, intelligence and connectivity are the three key technology components propelling this revolution. Industry 4.0 introduced a cyber-physical world through the integration of operations and information technologies, big data, cloud computing, additive manufacturing, advanced robotics, augmented and virtual reality, and the internet of things (IoT) [14-20]. Significant progresses in research and development is made possible by additive manufacturing [21-25]. Industry 4.0, with its rapid advancements in digitalization and artificial intelligence (AI), internet of things (IoT), and other technologies, might impact production processes as a
Some of the key innovations of fourth industrial revolution used in automobile industry are described in Table 1. The digital transformation of the production sector has resulted from the integration of new technologies with existing systems and processes along the supply chain and value chain [15].

Like any other industries, the automotive sector is changing dramatically. Industry 4.0, the fourth industrial revolution, is transforming the way cars are built, driven, and maintained. This has a tremendous impact on the automobile business. It's widespread in the sector, and Industry 4.0 and the ongoing digitalization of the whole value chain are major drivers of it. Industry 4.0 has boosted the potential for digital transformation in the automotive industry and has made it more significant for dealers, original equipment manufacturers (OEMs), suppliers, captive finance companies, and other players in the ecology of mobility [33]. All things taken into account, Industry 4.0 is drastically altering the automobile industry by improving its efficiency, connection, and capacity to react to rapidly changing consumer demands and technological advancements.

4 Automobile materials in industry 4.0

Material science constitutes a fundamental and intersectoral technology in Industry 4.0. One term used frequently to describe materials engineering is "innovation driver". Shorter production and development cycles, a variety of intelligent self-learning technologies and new business strategies leads to the trends in the market as a result of ICT advancements [34, 35]. Improvements have been made in material quality, production efficiency, maintenance, operation, and recycling. Figure 1 illustrates material solutions made possible by Industry 4.0 innovations.

Industry 4.0 technology enables a range of material solutions that enhance the productiveness, transparency, and adaptability of vehicle inventory management. The following material-related solutions for automobile inventory are now possible because of Industry 4.0.

![Material solutions by Industry 4.0 technologies](image_url)

**Fig. 1.** Material solutions by Industry 4.0 technologies
4.1 Smart packaging materials
Put RFID tags or QR codes on your intelligent packaging materials. Supply chain traceability and tracking can be performed in real time with the aid of these materials, ensuring accurate and automated inventory control.

4.2 Connected RFID components
Affix RFID tags to particular automotive parts. This minimises error rates, improves overall supply chain transparency and makes it possible to trace inventory items in real time. It also helps with accurate inventory counts.

4.3 Digital twin sources
Digital twin technology should be applied to inventory goods. Digital twins enable the virtual replication of genuine materials, enabling simulations and studies to predict maintenance needs and optimum storage conditions.

4.4 3D-Printed inventory materials
As needed, create inventory parts via 3D printing. The inventory system is therefore more efficient and cost-effective since there is no longer a requirement for extensive spare part storage because components may be generated as needed.

4.5 Events-based material traceability chain
Track the provenance of materials with blockchain technology. Blockchain technology provides an immutable and transparent transaction ledger, ensuring a secure and traceable record of the origin, movement, and validity of materials inside the inventory.

4.6 Adaptable and versatile shelving for inventory
Use materials for shelves that are flexible and adaptable that can be quickly reconfigured. Automation and robotics enabled by Industry 4.0 can dynamically improve inventory shelf layouts to adapt to changes in demand or manufacturing requirements.

4.7 Sensor-integrated storage receptacles
Store containers with sensors to monitor their environment. These sensors ensure optimal material maintenance and reduce the likelihood of degradation or damage by keeping an eye on temperature, humidity, and light exposure.

4.8 AI-enhanced packaging substances
Offer artificial intelligence (AI) based enhanced packaging materials. Algorithms employed in artificial intelligence (AI) may assess historical data and predict the optimal configurations for packages, saving space and boosting material density in storage.
4.9 Eco-friendly and sustainable packaging

Accept packing materials that are sustainable and kind to the environment. Utilising recyclable or renewable resources supports environmentally friendly inventory management practices, which are essential to Industry 4.0’s focus on sustainability.

4.10 Predictive maintenance materials

Incorporate tools that facilitate the execution of predictive maintenance strategies. Embedded sensors enable materials to monitor deterioration, providing predictive maintenance algorithms with the necessary data to optimise maintenance schedules and minimize downtime.

4.11 Workstations for human-machine collaboration

Collaboration: Using materials that encourage collaboration between people and machines, build workstations. Industry 4.0-powered robots may work side by side with human operators, and workstation materials that make it easy to access inventories and tools should promote productive collaboration.

4.12 Modular shelving systems

Install systems for racks made of flexible materials. These systems allow for quick adjustments to accommodate for changes in inventory size, component dimensions, and other variables, hence facilitating a flexible and adaptable inventory management strategy. By employing these material solutions in the framework of Industry 4.0, automakers and suppliers can enhance their inventory management practices, save expenses, boost efficiency, and implement adaptable and sustainable procedures.

5 Material management in automobile industry

Coordinating the type, amount, location, transportation, and timing of various commodities used by manufacturing businesses in development is referred to as materials management. In the automotive business, material management, especially with regard to inventory, is essential to maintaining effective supply chain operations, cutting expenses, and guaranteeing seamless production processes.

Fig. 2. Primary reasons for material management
From the time of their inception to their integration into the manufacturing process, it is the planning, directing, supervising, and synchronizing the activities related to the material and inventory requirements [36-38]. Figure 2 describes why materials management is crucial.

### 6 Significant technologies of industry 4.0 used in automobile industry

The next phase of industrial transformation, increased efficiency, and better plant process integration are all made possible by industry 4.0 technologies when implemented correctly. To cut down on energy use and boost overall performance, strategic actions and choices can also be made [39, 40].

Digital technologies are being integrated into manufacturing and industrial processes, a phenomenon referred to as Industry 4.0, or the fourth industrial revolution. Vehicle management systems can function much better after implementing Industry 4.0 technologies. Some of the significant technologies are discussing in Table 1.

<table>
<thead>
<tr>
<th>Sr No.</th>
<th>Technology</th>
<th>Description</th>
<th>Impact on vehicle management systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Internet of Things (IoT)</td>
<td>Allows for real-time data transmission and monitoring by connecting devices and sensors.</td>
<td>Improves fleet management decision-making through data-driven analysis, makes predictive maintenance possible, and monitors vehicle health more effectively.</td>
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<td>2</td>
<td>Artificial Intelligence (AI)</td>
<td>Uses algorithms based on machine learning to analyze data, find patterns, and make decisions.</td>
<td>Allows for the use of sophisticated analytics to improve autonomous driving, forecast malfunctions, and maximize vehicle performance.</td>
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<tr>
<td>3</td>
<td>Big data analytics</td>
<td>Extracts valuable insights by processing and analyzing vast amounts of data.</td>
<td>Increases operational efficiency in maintenance and logistics, facilitates data-driven decision-making, and enhances vehicle diagnostics.</td>
</tr>
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<td>4</td>
<td>Augmented Reality (AR) and Virtual Reality (VR)</td>
<td>Builds realistic settings for design visualization, maintenance, and training.</td>
<td>Improves the training given to mechanics, helps with design development, and facilitates augmented reality-based diagnostics for vehicles.</td>
</tr>
<tr>
<td>5</td>
<td>Blockchain technology</td>
<td>Enables data sharing and transactions using a decentralized ledger that is transparent and safe.</td>
<td>Makes ensuring that the automotive ecosystem's supply chain is traceable, safe, and secure, and that transactions are transparent.</td>
</tr>
<tr>
<td>6</td>
<td>Cyber-physical systems (CPS)</td>
<td>Encourages real-time communication by combining computational and physical processes.</td>
<td>Encourages the development of linked, smart car systems for increased responsiveness, efficiency, and safety.</td>
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<td>7</td>
<td>3D Printing/Additive manufacturing</td>
<td>Builds things layer by layer and provides fast prototyping as well as bespoke component production.</td>
<td>Cuts lead times, facilitates flexible manufacturing methods for vehicle production and maintenance, and permits on-demand fabrication of spare parts.</td>
</tr>
<tr>
<td>8</td>
<td>Robotics and automation</td>
<td>Uses robotic devices to do material handling, welding, and assembly operations.</td>
<td>Increases production costs and yields higher-quality cars by increasing...</td>
</tr>
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</table>
7 MRO parts inventory management

MRO stands for Maintenance, Repair, and Operations Parts Inventory Management. Automotive and manufacturing equipment maintenance and repair (MRO) parts are essential to the continuing operation of these systems. To reduce downtime, maximise expenses, and improve overall operational performance, MRO part management must be done effectively. The MRO supply chain is experiencing previously unheard-of levels of efficiency, visibility, and responsiveness due to the use of cutting-edge technology in the context of Industry 4.0, which is transforming traditional inventory management procedures.

The fourth industrial revolution, also referred to as Industry 4.0, was born out of the dynamic automotive industry's fusion of digital technologies with conventional manufacturing methods. Smart technology, data analytics, and automation are being incorporated into many facets of supply chain and production management, marking this revolutionary era. The management of auto parts inventories for maintenance, repair, and operations (MRO) is one crucial area where Industry 4.0 is having a big impact.

8 Conclusion and future scope

Smart industry elements are being implemented in many major and medium-sized industries. The automotive industry is also utilising these cutting-edge technologies to enhance their manufacturing processes, supply chain networks, material quality, and material management. They've had incredible outcomes from it. Many businesses, notably the auto industry, are still debating whether to implement these technologies. The administration of automotive materials has become easier due to smart materials and industry 4.0 technology. Better material handling has also reduced material failure, which eventually leads to safer working conditions, higher-quality products, and more profitability with less inventory management cost. The supply chain becomes more transparent, risk-free, optimised, efficient, and profitable with the implementation of the Internet of Things, Artificial Intelligence, Machine Learning, Deep Learning, and Virtual Reality processes. In automobile sector, they should evaluate carefully their needs before deploying Industry 4.0 technologies. It is also possible to prevent industrial accidents brought on by material failure. Early detection of material flaws will save significant additional expenses and improve worker safety.

In future, Industry 4.0 will be upgrade to Industry 5.0 for better efficiency of automotive inventory management by using more advanced and significant technologies. Industry 5.0 hasn't been defined or embraced broadly yet. But our ability to forecast future events is limited to applying the insights from the automotive sector to the overall patterns of Industry 4.0 and the continuous advancement of technology. In future, the advanced technologies like Artificial Intelligence, Neural Networks, Deep Learning, Machine Learning, Smart Manufacturing and Automation, Internet of Things, Supply Chain Digitalization and Eco System Development will lead to more efficient and durable automobile manufacturing to produce better autonomous and electric vehicles, hydrogen-fueled vehicles and flex-fueled vehicles with improved connectivity, customization, personalization, sustainability, collaboration and data security as well as privacy.

|   | Cloud computing | Gives users online access to services, storage, and computer resources whenever they need them. | Enhances connection and scalability in vehicle management by facilitating real-time data exchange, remote fleet monitoring, and teamwork. | manufacturing efficiency, accuracy, and consistency. |
It's essential to remember that Industry 5.0 is still in its early stages of development, and as it does, more details about its characteristics and consequences may become evident. Furthermore, a number of factors, such as regulatory changes, market needs, and technology breakthroughs, will influence growth in the automotive sector.

References


4. M. Ammar, A. Haleem, M. Javaid, R. Walia and S. Bahl, "Improving material quality management and manufacturing organizations system through Industry 4.0 technologies."


