REVIEW OF DIGITALIZATION USING ARTIFICIAL INTELLIGENCE MATURITY MODELS: THE CASE OF AMERICAN AUTOMOTIVE SMES

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ABSTRACT

The purpose of this study is to review studies related to Artificial Intelligence (AI) maturity models (MM) in automotive manufacturing in a systematic manner. SMEs in the automotive industry must embrace digitalization to remain competitive. SME's employ a large segment of the USA's workforce. SMEs had not been aggressive in digitalization due to scarce funds, but the benefits of operational efficiency, quality improvement, cost reduction, and innovative culture have made it attractive to consumers. A growing number of operations are being digitalized using Artificial Intelligence techniques. In this paper, AI applications in SMEs are examined through the lens of an AI maturity model.

KEYWORDS

Industry 5.0, Maturity Model, Artificial Intelligence, Maturity level & digitalization

1. INTRODUCTION

In the 1940s, the programmable digital computer was invented, which led to the beginnings of AI. After this, the USA, British, and Japanese governments funded several projects, but it wasn't until the dawn of the 21st century when machine learning applications started generating AI interest and investments. AI can deliver sophisticated solutions to advance manufacturing. Although the changeover will take time, the benefits are likely to be endless. In artificial intelligence (AI), algorithms or computerized systems resemble human mental processes [1]. In the last few decades, the field of AI has made rapid progress in developing decision-making intelligence after the early days were characterized by overpromises and under-delivery [2]. Data is a crucial component of AI, since it is used to train algorithms to detect patterns based on the data collected [3]. Data and computing power are required by AI researchers to build more powerful algorithms [1].

The development of AI technologies was boosted by a summer workshop conducted by mathematician John McCarthy at Dartmouth College in 1956, which looked at some foundational problems. AI techniques like machine learning, computer vision, deep learning, automation, and robotics are now the subject of pioneering research. In 2019, the Artificial Intelligence in Manufacturing Market was worth USD 1.82 Billion, and by 2027, it is predicted to be worth USD 9.89 Billion [4]. One third of global GDP is produced by the industrial sector, and half of global energy consumption comes from it [5]. A new study shows that 58% of manufacturers are positively interested in artificial intelligence, but only 12% are using it [6].

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AI will provide the most job security to those who possess creativity and management skills. The number of publications on artificial intelligence in manufacturing has increased exceptionally over the last 40 years, attracting much attention within the scientific community [7]. A growing number of companies are investing in hybrid technology systems to manage inventory, control quality, and optimize production and costs. Expert systems and robot localization, as well as visual surveillance, are less likely to be used by them. Technology can now be valued based on core use cases [8]. AI is used to simulate human reasoning, learning, planning, and other thinking activities, thus solving complex problems that were previously only solvable by human experts [9]. AI is particularly useful for automating learning, acquiring, processing, and using knowledge to perform tasks, enabling human decision-making processes to be improved through improved knowledge.

Achieving the goal of AI rivalling human abilities remains a work-in-progress, and it is uncertain if such a goal can be achieved [10]. Through technological maturity and integration with a variety of technologies, AI has become more relevant. There has been development in computing and chip design as well as neural network algorithms, which have developed into deep learning. There has also been convergence with technology such as augmented reality, robotics, 5G, virtual reality, and the internet of things [11]. There is a growing recognition among companies that they do not want to climb an artificial intelligence mountain. To achieve new heights, they just need to keep taking the right, tiny steps [12]. AI has triggered significant societal concerns, ranging from technological unemployment to the dominance of algorithms at work and in everyday life [13].

The SME sector employs 61.7 million workers in America, which is 46.4% of the total workforce [14]. AI is being funded by governments in advanced economies and large technology companies. Due to previous reviews not adequately addressing AI's use and advancement in engineering and manufacturing, this review is being conducted. The term "SMEs" is used in this paper to describe automotive small and medium enterprises.

MMs exist in different domains, and the goal is to answer the following questions.

RQ1 What is the role of AI maturity models in automotive manufacturing?
RQ2 How does the literature review describe different stages of maturity model?
RQ3 What are the important characteristics and goals of AI maturity models?

The current AI MMs are systematically reviewed to determine the dimensions for assessment. Organizations can use the AI Maturity Assessment to evaluate their current AI capabilities, identify gaps and areas for improvement, and create a guideline to build more successful AI programs [15]. The aim of this study is to illuminate the research gap and to guide future studies that need to consider the dimensions noted above. The rest of the paper is divided into the following sections: Section 2 and 3 presents a SWOT and PESTLE analysis of SMEs. Section 4 provides a literature review. Digital strategy is discussed in section 5. A description of AI MM for the aerospace industry can be found in section 6. Future Challenges is discussed in section 7. The conclusion of this study is in section 8.

2. SWOT FOR SMES

SME digitalization efforts and progress are discussed in this section

Table 1. SWOT

Strengths	**Weaknesses**
• An organization structure that is more flexible and easier to adapt. • The market share of electric vehicles has increased.	• Recruiting skilled workers is difficult • Inadequacies in R&D infrastructure • The cost of investment is high
Opportunities	**Threats**
• Assistance from the government. • Comparatively lower production costs.	• Market competition is intense. • Relocation of manufacturing hubs

- Strengths

An increase in the market share of electric vehicles: EVs have a lot of different components than conventional vehicles, especially the electric drive units, battery packs, and battery modules. Non-American SMEs have an entry barrier since they must start from scratch.

- Weaknesses

There aren't enough skilled employees: long-term training is needed. Investment costs can be a barrier since they are high.

- Threats

The American automobile market is very competitive with many new companies coming in and earlier manufacturing volumes are declining. Automobile manufacturing is shifting to emerging economies like China and India from developed markets.

- Opportunities

Digitalization efforts are being supported by the government. New manufacturing techniques lower production costs compared to conventional methods.

Since the early days of automobile development to the current development of electric and autonomous vehicles, the automotive industry is constantly evolving.

3. PESTLE ANALYSIS

Businesses use pestle analysis to track the environment in which new products or projects will launch (see Table 2).

Table 2 PESTLE

Political	**Economical**
• In the United States, the auto industry is growing.	• Pandemics hit the automobile industry
Social	**Technological**
• Skilled talent is in short supply in the auto industry.	• The digital revolution is gaining traction.
Legal	**Environmental**
• There are regulations and restrictions in the auto industry.	• Impacts of manufacturing on the environment.

4. LITERATURE REVIEW

Over 30 million SMEs with fewer than 500 employees make up 99.9% of all American businesses. Digital tools aren't used favourably by 80% of U.S. SMEs [16]. AI maturity models help organizations evaluate their progress and identify the changes they need to make to be more productive and efficient. The dimensions above are discussed below. The use of AI to mitigate adverse environmental impacts is discussed in Sustainability in AI [17]. To increase sustainability coverage and remit the most profit to stakeholders, organizations need to quantify their environmental, financial, and social impacts [18]. An AI implementation that is connected requires the involvement of a multidisciplinary team with expertise in AI, data science, manufacturing processes, and OT and IT infrastructure. Connecting machines, processes, workplace health and safety, and managing product lifecycles all requires technical infrastructure [19].

Resilience is facing situations and recovering from them, and disruption is something we're all worried about [20]. In today's world, organizations see AI as a strategy to innovate by controlling and commanding, knowing their objectives, and being opportunistic [21]. Leadership needs to leverage AI to gain a competitive edge, and there needs to be inspired and proactive leadership to make AI investments [22]. Supporting customers with AI allows for deeper insights and a better user experience that indirectly builds mass personalization [23]. It's important to have a healthy innovation culture to prosper economically and make technology safer [24]. McKinsey found that 70% of manufacturers use or plan to use AI to improve operations in production, which suggests that many manufacturers are seeing the value of AI and are interested in adopting it [25].

A comprehensive and systematic search was conducted following the steps of identification, screening, eligibility, and inclusion. Identifying relevant records required a title and subject search in various academic databases, including ABI/Inform Global, Springer, ScienceDirect, IEEE, ACM Digital Library, and ProQuest. A manual search using Google and Google Scholar were also used to find papers, conference proceedings, books, and technology reports. In this paper, different search terms were used to identify some keywords based on the research questions such as "Artificial Intelligence", "Manufacturing", "SME", "Maturity Model", and "Artificial Intelligence Maturity Model". A good search strategy involves extracting individual terms from the research question and then using Boolean "ORs" and "ANDs" to perform advanced searches.

Table 3. Overall comparison of AI dimension

Author	Connectivity	resilience	sustainability	Expansive growth	Strategy	Leadership	Customers	Culture	Production
[26]	X	X		X	X		X		X
[27]	X	X	X	X	X	X		X	
[28]						X			X
[29]	X	X	X		X	X	X		X
[30]	X			X	X	X	X	X	X

Figure 1. Dimensions

As a result of the above comparison, the AI maturity model can be improved by identifying the shortcomings (see Figure 1). Since SMEs have lagged other domains in digitization efforts, the research, assessments, and implementation requirements are more intense for them. To save money and gain a competitive edge, digital transformation combines different technologies. SMEs will benefit if an AI maturity model fits their requirements and helps assess AI maturity levels.

5. DIGITAL STRATEGY

Regardless of the type of business, differentiation, leadership, and focus are Porter's three generic strategies that anyone can use. A digitalization strategy requires the right culture, infrastructure, and capabilities, which can be achieved with tailored transformation measures and step-by-step

transformation procedures. Digital transformation is changing how companies create value and in digital transformation, it's the inversion of a company that makes the most money. This becomes possible when companies move from creating value independently to orchestrating value with other companies. The most successful companies partner with users, developers, and merchants at scale. A high market cap is not achieved through automation or shifting labour to capital, but rather by coordinating external value creation.

6. AI MM FOR THE AUTOMOTIVE SME MARKET

In a MM, the organization's preparedness is assessed, and faults are identified. These weaknesses need to be fixed and corrective actions are needed to move forward. AI MM needs to see how it aligns with Industry 5.0 and forge a more sustainable, human-centric, and resilient industry. Collaboration between humans and advanced technology is the goal of Industry 5.0. While Industry 4.0 is a technology-driven industry, Industry 5.0 is a value-driven one [31]. From total manual production to using operating machines and eventually assembly lines, the previous three industrial revolutions revolutionized our manufacturing industries. AI-related technologies are assessed with the MM, which extends smart manufacturing MMs by adding specific technical and nontechnical competences of these technologies.

It's time to make the organization human-centred, so MM doesn't have to be just about technology. People are the key to a successful digital strategy. Future SMEs need to be resilient so they can handle disruptions and assist vital assets. SME's have realized that sustainability measures can boost their recovery, speed up growth, and make them more profitable [32]. It's going to be tough for future SMEs to gain a competitive edge. During a global shortage of workers and supply chain uncertainty, we're transitioning from predictable internal combustion engines to variable and software-driven next-generation vehicles, including electric vehicles (EVs), hybrids, and autonomous vehicles.

Is it time to refocus our current assessment criteria because of the happening EV market? The digital transformation is the key to success, and EV manufacturers can benefit from a digital backbone [33]. In contrast to established automakers, new EV entrants are leading disruptive change. Electric vehicles (EVs) should be included in the MM assessment to help assess progress to EV and zero-emission vehicles. A vehicle brand is currently known by its engine manufacturer, but in the next ten years, it'll be known by its software provider (including AI-powered autonomous driving, advanced infotainment, etc.).

In the world of intelligent manufacturing, AI technology helps develop new models, system architecture, and technology systems. There are three key technologies that make IoT work: 5G, Big Data, and AI. Data is provided by IoT frameworks, and AI uses it for specific functions. The automotive industry is changing thanks to 5G and AI [34]. In comparison to cabled fibre optic networks, 5G provides a feasible broadband networking option [35]. Industrial IoT needs 5G's high performance and low latency [36]. Factory automation is an example of a latency critical IoT use case that involves real-time control of machines and systems and has latency and reliability requirements [37].

Automotive progress has been helped by electrification and automation, as well as advances in the communications industry, including 5G and 6G. By improving reliability, lowering latency, and guiding hyper automation, 6G will open new growth potential in business. Sixth generation (6G) mobile communications are also essential for Industry 5.0 to unseat Industry 4.0. High-quality services, extensive IoT infrastructure, AI capabilities, and other requirements will be supported by this network.

7. FUTURE CHALLENGES AND OPPORTUNITIES

Enterprises can improve their competitiveness by embracing intelligent transformation, which is the trend of the future [38]. Production is expected to increase by 40% by 2035 thanks to AI technologies. Across different industries, economic development will increase by an average of 1.7%. [39]. Although AI can surpass humans on some very particular tasks, humans still noticeably outperform in all real-world tasks necessitating intelligence. During this era of intelligent work, artificial intelligence has subverted traditional work methods and is widely used in medicine, self-driving technology, image recognition, robotic manufacturing, intelligent assistance, supply chain management, etc., using devices and technologies like cameras, video, light detection and ranging (LiDAR) and motion tracing [40]. Small and medium-sized enterprises have difficulty joining the intelligent manufacturing wave, and their implementation of intelligence is limited [38]. Our pace of invention, however, must keep up. Approximately seventy-five billion IoT-connected devices are expected in use by 2025, an almost threefold increase from 2019, and connecting all these devices with intellectual abilities will be a considerable challenge. [41].

AI's scope is also evolving, as it shifts from being "just a tool" to being a sci-fi creation that threatens mankind [42]. Although AI is still in its infancy, it has reached milestones that a few years ago seemed inconceivable. Christof Koch, a neuroscientist at the Allen Brain Institute and an AI advocate, believes humans will need to enhance their brains to compete with artificial intelligence [43]. Global competition and the need to develop a green economy have forced organizations to implement AI, and IoT in production flows. In the age of intelligent manufacturing, the manufacturing industry needs to lead innovations to compete globally [44].

8. CONCLUSIONS

An uncertain and turbulent environment could result in mandatory closures, logistics bottlenecks, supply issues, and a volatility in consumption trends which would have major consequences for the manufacturing industry. Manufacturers' success and survival are closely linked to their ability to embrace advanced digital technologies, such as artificial intelligence. Scholars and practitioners alike have become increasingly interested in AI over the last decade due to the growing amount of data and information that firms collect and process.

Manufacturing plants can do more than just track operations with machine learning algorithms. It is possible to contain inefficiencies, assess alternative strategies, and conduct new protocols simultaneously without affecting the supply chain [45]. AI and digital transformation are revolutionizing manufacturing. As organizations assess their capabilities, they need a robust AI maturity model that details incremental improvements. Present maturity models have shown deficiencies and therefore need to be addressed as per the AI focused SME maturity model requirements. The lack of technological awareness among SME managers, such as "unclarity regarding the benefits of AI initiatives" and "insufficient understanding" of AI, is a problem [46].

Manufacturing companies around the world benefit from investing in artificial intelligence (AI) and optimizing their productivity [47]. Several manufacturers do not have the in-house capabilities and are risk-averse to upscaling a factory due to the high cost and lack of skills required for AI adoption [48]. A maturity model for AI needs to be developed to measure current state and developments, and concrete recommendations have been presented for the model.

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