REVIEW OF AI MATURITY MODELS IN AUTOMOTIVE SME MANUFACTURING

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ABSTRACT

This study reviews studies on Artificial Intelligence (AI) maturity models (MM) in automotive manufacturing. To stay competitive, SMEs in the automotive industry need to embrace digitalization. SMEs employ a large segment of the USA's workforce. The benefits of operational efficiency, quality improvement, cost reduction, and innovative culture have made SMEs more aggressive about digitalization. Digitalizing operations with Artificial Intelligence are on the rise. 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, Strategy & 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].

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.

In automotive manufacturing, Digital Transformation means applying digital tools and methods to make the manufacturing process more efficient and cheaper. A digital transformation emphasizes data-driven and AI to derive info on manufacturing processes, optimize production planning, and improve quality. Having digital transformation has allowed businesses to reduce the cost of production and time in the manufacturing process as they face cutthroat competition and innovation is the key. Robotics and automation allow for real-time analysis of data, which improves productivity. 5G, AI, additive manufacturing, and the Internet of Things are revolutionizing product innovation and manufacturing efficiency. Automakers are investing more and more in developing electric cars to meet the growing demand for eco-friendly vehicles, but these need new suppliers also.

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]. This study aims 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: Sections 2 and 3 present a SOAR 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. SOAR FOR SMES

SME digitalization efforts and progress are discussed in this section. Using a SOAR Analysis is a good way to plan strategy. The goal is to create a vision that is energizing to work toward by combining data about an organization's current position with people's ideas and dreams. An organization's SOAR analysis uses the experiences of employees at all levels and across all departments, while a SWOT is typically a management-led exercise.

Table 1. SOAR

Strengths	**Aspirations**
• More flexible and adaptable organizational structure. • Ability to innovate, knowledge, skills, experience, and accomplishments.	• Trying to stay fast and flexible while working sustainably in a known field. • Mission, vision, values, and priorities are clear from the top. • SME's key stakeholders are customers, employees, business partners, and communities
Opportunities	**Results**
• Government assistance. • Making the organization more efficient and meeting customers' needs. • Expansion can be helped by innovative funding methods.	• Technical staff has more time. to develop cutting-edge skills, which helps the organization work better. • Acquiring new clients. • Keeping growth positive, without being weighed down by big, bureaucratic projects.

- 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.

- Aspirations

There aren't enough skilled employees: long-term training is needed. Stakeholders play a big role in the success of any small business. The stakeholder's relationship with the small business generates goodwill for the company.

- Results

The results serve as a benchmark for progress and help track strategy effectiveness. Achieving results keeps businesses on track and keeps them accountable.

- 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 has been constantly evolving. After SOAR analysis is complete, the organization can move on to other stages like evaluating ideas and proposals, creating a compelling vision and mission, and setting goals.

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
[31]					X	X	X	X	
[32]				X	X	X	X	X	
[33]				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

Digitization is the process of converting analogue to digital. The digitalization of a business means changing a business model and providing new revenue and value-producing opportunities, and it is about moving to a digital world. Today, digital skills are a necessity for success in the workplace, industry, and region. It's no secret that people's jobs change as companies implement digital technologies. In digitalization, automation plays a big part, whether it's shifting work roles or transforming business processes. Digitalization improves data transparency and process efficiency, and it should boost your bottom line.

Technology is enabling manufacturing companies to become more efficient and customer-centric, as well as stay competitive and adapt to changing business conditions. Automating production processes, gathering, and analyzing data, and facilitating speedy decision-making through tools like the Internet of Things, artificial intelligence, robotics, and cloud computing can help optimize business operations. Digital technologies like AI, machine learning, and big data analytics can help manufacturers gain new insights and improve their products. Finally, businesses and industries need strategic plans to sustain a company's vision, market share growth, brand equity, employee and product effectiveness, profitability, and stakeholder satisfaction.

These five rules will help get the most out of digital strategy (see Figure 2) [34].

- Assess the Strategic Impact of Digital

The impact and opportunities of digital will vary based on industry and function, so a good digital strategy starts with a deep understanding of the competitive environment.

- Set Your Digital Ambition High

Most digital strategies fail due to too little ambition instead of too much because first movers and smart fast followers win.

- Place Big Bets

The best way to manage priority initiatives is as a portfolio and roll out the ones with the most short-term impact first to free up the resources needed for more strategic, high-impact initiatives later.

- Build New Strategic Muscles

A properly ambitious digital strategy requires new capabilities and cultural shifts.

- Manage Transformation Actively

It's important to keep the momentum going, track progress against goals, milestones, and metrics, and signal when it's time to change directions [34].

Figure 2 The Five Rules of Digital Strategy

Business owners often change their value creation because of using new technologies. These relate to the impact of digital transformation strategies on firms' value chains, i.e. how far digital activities deviate from traditional – sometimes still analogue – core businesses.

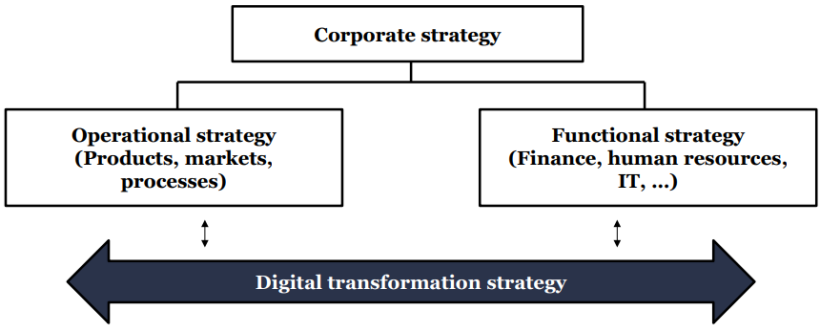

Figure 3 Relation between digital transformation strategy and other corporate strategies

The digital transformation transforms key business operations, products, and processes, as well as organizational structures and management concepts. All organizational and functional strategies should be closely aligned with digital transformation strategies (see Figure 3). The financial side of the transformation is both a driver and a constraint [35]. Digital transformations can be financed from within the company as well as externally. Digital transformation is not just about fixing past mistakes but creating new opportunities for the future. Regardless of industry or firm, digital transformation strategies share some elements: four essential dimensions which are, the use of technologies, changes in value creation, structural changes, and financial aspects (see Figure 4) [35].

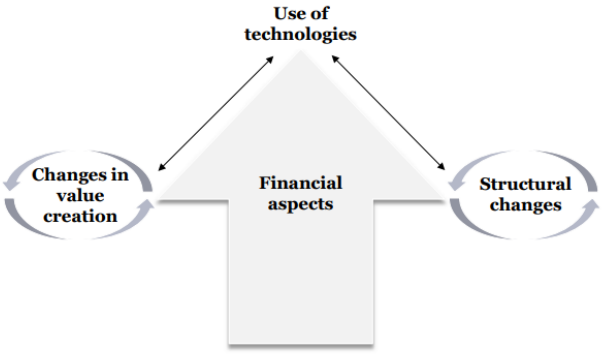

Figure 4 Digital transformation framework: balancing four transformational dimensions.

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. In standalone companies, network effects don't happen, but if companies look at their business frame in an ecosystem, it might be easier. Multiplayer benefits can be realized if companies organize around shared value [36].

Uber and Airbnb are causing severe systemic effects in industries and markets and challenging the existence of dominant firms. A lot of attention is being paid to such radical digital innovation - often called digital disruption - and its wider systemic effects. Firms heavily invested in old conditions are generally perceived as disrupted by digital disruption from their perspective. Established firms face severe pressure to respond to new digital processes or artifacts, and such responses can lead to radical changes in operations. The digital revolution is therefore an aggregated effect that's both triggered and spurred by a lot of digital innovations, some of which may create digital disruptions [37].

6. AI MM FOR THE AUTOMOTIVE SME MARKET

In an 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 technology-driven, Industry 5.0 is a value-driven one [38]. From total manual production to 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 competencies 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 [39]. 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 [40]. 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 [41]. In comparison to cabled fibre optic networks, 5G provides a feasible broadband networking option [42]. Industrial IoT needs 5G's high performance and low latency [43]. 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 [44].

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 [45]. 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%. [46]. 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 [47]. Small and medium-sized enterprises have difficulty joining the intelligent manufacturing wave, and their implementation of intelligence is limited [45]. 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. [48].

AI's scope is also evolving, as it shifts from being "just a tool" to being a sci-fi creation that threatens mankind [49]. 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 [50]. 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 [51].

CONCLUSIONS

An uncertain and turbulent environment could result in mandatory closures, logistics bottlenecks, supply issues, and 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 [52]. 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 [53].

Manufacturing companies around the world benefit from investing in artificial intelligence (AI) and optimizing their productivity [54]. 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 [55]. Different analysis tools like SWOT can also detail the digitalization efforts and progress in SMEs [56]. A maturity model for AI needs to be developed to measure the current state and developments, and concrete recommendations have been presented for the model.

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