World Academy of Science, Engineering and Technology
International Journal of Industrial and Manufacturing Engineering
Vol:15, No:10, 2021

Technological Applications in Automobile Manufacturing Sector: A Case Study Analysis

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***Abstract*—**The research focuses on the applicable technologies in the automobile industry and their effects on the productivity and annual revenue of the industry. A study has been conducted on six major automobile manufacturing industries represented in this research as M1, M2, M3, M4, M5 and M6. The results indicate that M1, which is a pioneer in technological applications, remains the market leader, followed by M5 and M2 taking the second and third positions, respectively. M3, M6 and M4 are the followers and are placed next in positions. It has also been observed that M1 and M2 have entered into an agreement to share the basic structural technologies and they maintain long-term and trusted relationships with their suppliers through the Keiretsu system. With technological giants such as Apple, Microsoft, Uber and Google entering the automobile industry in recent years, an upward trend is expected in the futuristic market with self-driving cars to dominate the automobile sector. To keep up with the market trend, it is essential for automobile manufacturers to understand the importance of developing technological capabilities and skills to be competitive in the marketplace.

***Keywords*—**Automobile manufacturing industries, competitiveness, performance improvement, technological applications.

I. Introduction

To remain competitive in the global business environment, manufacturing organisations need to consistently improve the quality, reliability, on-time delivery and customer service. Further they need to rapidly develop new products and be flexible in manufacturing their products. The advances in technologies have enabled manufacturing organisations to develop the competitive capabilities required for competing in the market. The customer requirements are continuously changing and so the automobile manufacturers are not only required to achieve the economies of scale but also need to keep up with the changing customer demand. This requires a continuous improvement and flexible approach which could be achieved using the latest technologies in the manufacturing process. This research analyses the technologies used by the major automobile organisations and the effects on the organisation's production and annual revenue.

This research critically evaluates the manufacturing technologies used in the automotive industry and its effects on the performance of the organisation. The technologies used by automobile manufacturing sector have been compared, analysed, and evaluated. This study provides an insight on to the importance of applying technologies in automobile manufacturing sector to remain competitive in the market.

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II. Literature Review

The automobile manufacturing sector remains competitive by continuously implementing new technologies in its production and assembly lines. Technology have not only reduced errors in the production but have greatly increased the efficiency and productivity. The researchers [1] have studied the application of Artificial Intelligence (AI) in manufacturing. The researchers state that the integrated system provides features to digitalization and provide flexible service to the customer. In [2], the researcher has presented that the application of artificial intelligence in manufacturing industry improves the output ratio, quality, and innovation. The researcher also presents that the automation software used in manufacturing organisations very well detects errors in the production line. Reference [3] reports that the automotive processes are used in manufacturing industry for producing better quality with reduced unit cost. Researchers [4] report that the manufacturing process could be monitored using sensors linked to Internet of things (IOT) and big data. The researchers have also presented the details of the Raspberry pi sensor, which could monitor and control the process and could determine the real-time speed using computational models. The researchers further state that an artificial intelligence agent could work with the automobile driver to ensure safety and comfort through integrated voice communication, enabling functions to increase alertness or lower tension, improve lighting, air conditioning, fragrances, and other human-machine interaction functions. Reference [5] presents that in 2017 more than $100 million in AI have been invested by Toyota Research Institute's subsidiary, Toyota Artificial Intelligence Ventures, and further state that it would spend an additional $100 million to focus on AI, automation, and robotics in future. The study reveals that implementing advanced technologies results in fully automated production lines, quick decision-making capabilities, improved production and quality with reduced cost, higher scalability and provides novel opportunities. Reference [6] have highlighted that the next revolution in automation is close and so the manufacturing sector need to be prepared for total integrative systems in which the supply chain, the expert team, the production line, and the quality assurance are all well-organised and coordinated through smart engine that could provide remarkable insights through expertise. The goal of the latest AI technology in

business is to set a milestone for automation in the mass market [7]. Reference [8] have presented that in Ford, AI is used in applications such as, process planning of vehicles, ergonomic analysis, customizing and translating the machine language and knowledge management. The researchers [9] have supported this by arguing that the challenges faced in automobile sector could be very well addressed using AI.

III. Case Studies

The automobile manufacturer M1 in its vehicle production process has implemented "lean manufacturing," and "Just in Time (JIT)" approaches [10]. While the philosophy JIDOKA has helped to automate the processes and JIT helped to meet the demand with instantaneous production, M1's manufacturing technology known as "Toyota Production System (TPS)" has helped to develop competitive advantage. JIDOKA denotes that a machine comes to a safe mode any moment when an irregularity arises. The JIDOKA technology is incorporated into the production process and so machines get simpler and more inexpensive, while maintenance becomes less tedious, allowing the construction of simple, slim, flexible lines that can adjust to varying levels of output volume [10]. Thus, M1's JIDOKA idea is based on the consistent growth of both human capabilities and achievements.

M2 is the fifth-largest automobile manufacturer. The Protegé, Mazda3, Mazda6, Miata, RX-8, MPV, and Tribute are among the organisation's US brands [11]. The company runs two primary production plants in Japan, as well as 15 other production facilities located across the world, including two Ford Motor Company manufacturing joint ventures located in Michigan and Thailand. M5 invested in M2 in 1979, and as a result it obtained a controlling 33.4% stake in the organisation on the verge of bankruptcy in 1996. As a result, to save the company, which was largely dependent on cutting costs, rebuilding, and launching a line of new models, M5 started a turnaround by engaging in cost-cutting, restructuring, and launching new models. M2's unique performance visibility, optimal driving position and heads-up cockpit concept are the core elements of the human-centric design philosophy [11]. M2 made use of a line of MZR engines which came in four displacements and engines were built using specialised machines, each of which performed a specific task [12]. Though practiced for a longer time, this was not an effective solution. Skyactiv technology was then introduced and with the use of Skyactiv mills, each engine could be altered to fit the architecture and displacement. CNC machines have helped to produce different engines such as gasoline and diesel mills flexibly at the same time and in line with the changing customer demand. With the use of these technologies, the time to machine an engine has reduced from six hours to one and a half hours.

M4, which has a market capitalisation of $42 billion, is India's largest vehicle enterprise and one of the world's top vehicle producers specialising in automobiles, commercial vehicles, passenger cars, transports, trucks, and military vehicles. M4 a wholly owned part of the $100 billion Group, was founded in India in 1945. The company is focusing on designing future mobility with emphasis on quality, innovation, design, and efficiency by investing heavily on technologies and engineering services. The company spends about 8% to 10% of its research and development expenditure towards emerging technologies. Reference [13] presents that the most known brands such as Jaguar, Land Rover and Tata Daewoo belong to the conglomerate, and all are structured differently. The specific areas of technological applications are in machine utilisation module, engine volume prediction, maintenance module, smart energy management and predictive quality management. Manufacturing execution system is used to schedule production, improve product quality, and generate real-time reports. Big data is used to analyse production, productivity loss, quality, and efficiency improvement. The integrated manufacturing environment gathers data on real-time losses in the assembly line with the use of Manufacturing Execution System (MES).

M5 founded in 1903, is ranked 11th on the Fortune 500 list of the nation's top corporations. The organisation has offered twelve brands under its control including brands that have passed on such as Edsel, Merkur and Mercury. Reference [14] presents that in addition to these, brands such as Mazda Land Rover, Jaguar and Volvo were given off to other businesses. Lincoln and Ford are part of brands under M5's ownership, the group also introduced world's first game sports car under the name Bronco. Additive manufacturing technology is used for quick prototyping, tooling, surface coating and die making. The researchers [15] have analysed the various types of materials used for additive manufacturing and have reported that utilising laser is the most efficient method for handling metal particles in the automobile sector.

M6 manufactures autos and light business vehicles [16]. The company was established in 1896 and headquartered in Paris, France. The company manufactures motorbikes, bikes, water powered motors, automobile segments and provides after sales services. The business division includes Vehicle Automotive, Vehicle Parts, Transportation and Logistics and Finance Division. The Automotive division performs pre-production planning, factory manufacturing and fleet sales of light commercial vehicles and automobiles branded with the P and C brands. The Automobile Equipment division performs interior frameworks, auto seats, control advancements and components. This division focusses on synchronising vehicle and cargo travel with vehicle transport. The Finance Division offers retail and discount financing to P and C customers and vendors [16]. The group developed Efficient Modular Platform [EMP2] and Common Modular Platform (CMP) in 2013. EMP2 was developed to manufacture wide range of body styles of compact and family cars and provides a single, streamlined platform for innovative and efficient solutions and it allowed a reduction of 70 kg in vehicle mass, 22% reduction in fuel consumption and elimination of 99% particulates. Common Modular Platform was developed in partnership with Dongfeng Motors China and the platform is electrified to provide efficient solution in terms of scalability, flexibility, and CO_2 emissions [16].

IV. Comparative Analysis

Toyota Production System (TPS) comprises of two segments, JIDOKA and Just-in-Time. The objective of TPS is to eliminate the waste termed as 'Muda'. Wastes are associated with overproduction, pausing, overstock, unnecessary movements, and unplanned shipping [10]. The company has teamed up with Robot Wars X so that the mechanical and synergistic robots are used for painting and welding. M1 advances its lean assembly by including both program guided tuggers and program guided trucks. Components are left in the drop-off-zones which are then fed to robots. On completing the procedure, the robots place the components on to the rack which are then moved to the next workstation by automated guided vehicles [17]. Automated Guided Container Transport System Robots help to automate long distance transport thus freeing up yards and improving packaging operations and eliminating the idleness of cranes and holder trailers. The other benefits for the company are excellent quality, increased productivity and on time delivery.

Mono-tsukuri Innovation, the technique used by M2 comprises of bundled product planning, common architectures, and flexible production. The products produced are transferable across different models and standard vehicle architectures. M2 design the vehicles not only based on model-based body forms but also use a component-based construction and sectional shape configuration to fit specific vehicle. This has helped the company to keep pace with the market demand [11]. M2 through its Mono-tsukuri Innovation had the option to create different product offering to keep up the economies of scale in spite of its low production capacity. Managers from product development, manufacturing, purchasing and supplier departments regularly meet to discuss the production plans for the next five to 10 years and work closely to accomplish the goal [18]. Thus, M2 could characterise the designs such as a fixed engineering concept, cross sections, machining method and transfer standard among few of the future models. This helped in design standards that are unable to be produced in low-cost regions and to maintain the required productivity level.

The press and weld shops at M3 are automated. The Press Shop pushes sheets of metal into pre-determined forms. Once welding is completed, the sections are connected in the weld shop. Robots enable chipping and to connect in narrow holes to execute spot-welding. The weld shop uses robots to perform three dimensional and three thousand of a millimetre hole directing, which welds various components of a skeleton. This automation enabled M3 to continually increase the usage. This resulted in better weld quality, increased yield, reduced waste, and less variable cost. Moving from labour-intensive to capital-intensive operations require preventive maintenance procedures to be followed for full-scale production to be achieved [19].

M4 outsources engineering services and develops Information Technology products and services. The company is expert in the design space and applies innovative methods in assembly through unified Connected Vehicle Platform (CVP). This enables the company to reduce the processing time and limit the manufacturing cost, thereby reducing the stock.

M5 utilises Additive manufacturing for three-dimensional printing. Prototyping is very expensive and three-dimensional printing replaces the expensive method by enabling to make different multifaceted model plans without the additional tooling and design needed for making the conventional prototype for individual components. This automated design not only helped M5 in achieving the efficiency, but also assisted in keeping up its sales despite market concentration. Additive manufacturing technology is used for making complex shapes along with regular components thereby consolidating production and assembly together. The mechanical properties of a finished component depend on the quality of the alloy material powder used and it is highly unlikely to vary it at the later stage. Specialty interaction, meaning a variation to the added plan is also possible and requires two to three hours to create a shape [20].

M6 adopted a three-step design approach which are initialization, macrosimulation and validation. M6 uses simulation and analytical methods as tools in this process. Simulation is carried out using software such as Arena. Verification and validation of the product functions are carried out using the design simulation. Simulation requires expert skills but is used to analyse the dynamic characteristics which are limited with analytical methods. Initial stages of automobile assembly at M6 involve moderate labour and machinery, robots are used in the intermittent stages for welding and applications, the consecutive stages involve a mix of labour and automation before moving to the paint shop and final assembly. The different technologies used by the manufacturing organisations and the output received have been presented in Table I.

TABLE I
Techniques Implemented and Outputs Achieved

Manufacturing organisations	Techniques Implemented	Outputs achieved
M1	TPS consisting of 1. Jidoka 2. Just-in-time	Improved quality & safety
M2	1. Mono-tsukuri Innovation 2. Skyactiv mills	Optimised manufacturing process & improved collaboration
M3	Automated Press and Weld shops	Improved driving performance & fuel efficiency
M4	1. Machine utilization module 2. Manufacturing Execution System 3. Predictive Quality Management	Improved efficiency & reduced inventory
M5	Additive Manufacturing	Combining manufacturing & assembly in a single step
M6	1. Efficient Modular Platform 2. Simulation techniques	Improved efficiency & better validation of new products

V. Results and Findings

The annual revenue of the different manufacturers and the number of units manufactured by each of them have been compared for the years from 2015 to 2019 and have been presented in Table II. M represents the different manufacturers, and the Production and Revenue details are compared for the years from 2015 to 2019. From the comparative analysis it has been observed that the manufacturer M1 has used the technology very well to improve its productivity and the annual revenue. The results indicate that M2 has moderately used the technology compared to M1 and that there are lots of opportunities for improving the efficiencies further. M4 have managed to transform its production process with the help of technology, however a slight drop in productivity has been observed. This indicates that M4 could further focus on improving its productivity. New technology implementation has helped M4 to manufacture cars at a reasonable price suiting to market needs. M5 managed to maintain the productivity rate steadily with the implementation of new technologies, however a slight mismatch between the organisation and the technology implemented have been observed. M6 has experienced a high increase in productivity with very reasonable increase in cost.

TABLE II
Production & Revenue Analysis

M	Production (Millions) Revenue ($Billion)	2015	2016	2017	2018	2019
M1	Production	10.1	10.2	10.5	9	10.7
	Revenue	246	253	253	266	272
M2	Production	15.4	15.9	16.1	16	16.6
	Revenue	26.5	30.2	28.8	31.2	32.1
M3	Production	3.1	2.9	3.3	3.4	3.5
	Revenue	25.8	27.2	26.6	31.2	34.8
M4	Production	1.01	1.08	0.93	1.04	1.03
	Revenue	37.8	39.9	39.4	42.2	43.4
M5	Production	6.4	6.42	6.4	6.4	5.4
	Revenue	158	163	169	176	156
M6	Production	2.9	3.1	3.6	3.9	3.5
	Revenue	54.6	54.1	62.2	74.02	74.7

The analysis indicates that M1 has remained as the market leader throughout the years from 2015 to 2019. M5 has retained its position as the second largest producer of automobiles. M6 has lost its position from being the third largest producer in 2015 to fifth in 2018. M3 improved from being the fourth largest automobile manufacturer in 2016 to the third largest manufacturer in 2018 by implementing latest technologies. M2 has positioned itself as fifth but have improved to fourth in 2018 and M4 has been observed as the sixth largest manufacturer throughout the period. The performance comparison has been presented in Table III. It is clear from the analysis that the adoption of the latest technologies has played a greater role in improving the performance and competitiveness of manufacturing organisations.

TABLE III
Performance Comparison of the Manufacturers

Manufacturer	2015	2016	2017	2018	2019
M1	1	1	1	1	1
M2	5	5	5	4	4
M3	3	4	4	3	3
M4	6	6	6	6	6
M5	2	2	2	2	2
M6	4	3	3	5	5

VI. Conclusion

Adoption of new technologies have played significant role in improving the performance and the competitiveness of manufacturing organisations. Moving towards a complete autonomous production level is the objective of all manufacturing organisations, however it requires lot of research and developmental efforts and resources. Adapting new technologies as and when the organisations move forward would help the manufacturing organisations to progress towards achieving the complete autonomous production. This study highlights the importance of technological applications and provides an insight on the advantages of adopting new technologies in automobile manufacturing sector.

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