Penerbit Akademia Baru

Journal of Advanced Research Design

Journal homepage:
https://akademiabaru.com/submit/index.php/ard
ISSN: 2289-7984

Malaysia's Manufacturing Landscape: Current Challenges and Production Strategies

Nor Anija Jalaludin[1], Amirul Syafiq Sadun[1,*], Saranjuu Chulakit[1], Hairulazwan Hashim[1], Suziana Ahmad[2], Nur Aminah Sabarudin[3], Muhammad Ashraf Fauzi[4], ZhiWen Wang[5]

1 Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Panchor, 84600 Muar, Johor, Malaysia
2 Faculty of Electrical & Electronic Engineering Technology, Universiti Teknikal Malaysia Melaka, 76100 Durian Tunggal, Melaka, Malaysia
3 Alps Electric (M) Sdn Bhd, Lot 3, Industrial Estate Phase 2, 26400 Bandar Jengka, Pahang, Malaysia
4 Faculty of Industrial Management, Universiti Malaysia Pahang Al-Sultan Abdullah, 26300 Kuantan, Pahang, Malaysia
5 School of New Materials and Shoes & Clothing Engineering, Liming Vocational University, Quanzhou 362000, Fujian Province, China

ARTICLE INFO

Article history:
Received 23 May 2024
Received in revised form 29 October 2024
Accepted 15 December 2024
Available online 31 December 2024

Keywords:
Manufacturing; production line; Malaysia

ABSTRACT

Manufacturing is a complex industry where various methods, tools and labour come together to produce large-scale products. Each product and industry have its unique systems, layouts and procedures. Understanding these intricacies is vital for efficiency, product quality and competitiveness among the industries. This paper aims to explore the basics of the local manufacturing sector, the different production processes used and common problems on the manufacturing floor. In a November 2022 survey with about 56 participants in Malaysia, data were collected on how each of the participants' industries operated, along with some common problems. Human, machine and system issues were identified as common concerns among the industries. Surprisingly, despite the rise of automation and Industry 4.0, 10% of production lines still rely entirely on manual labour and 80.4% are semi-automated, highlighting a continued dependence on human labour for various tasks, even in today's technological landscape.

1. Introduction

The manufacturing industry is responsible for producing finished goods on a large scale, employing various methods, tools, machines and labour [1,2]. This complex process primarily takes place on the shop floor of manufacturing facilities, where multiple production lines or work cells operate.

A production line is a sequence of operations that transform raw materials into finished goods through different processes. The finished goods can vary widely, including products such as phones, cars, steel, medicine, food and more, depending on the specific manufacturing sector's focus. This vast diversity leads to unique production processes, operating systems, production layouts and monitoring systems for each industry [3]. Understanding the complexities of each manufacturing

* *Corresponding author*
E-mail address: amirul@uthm.edu.my

https://doi.org/10.37934/ard.123.1.213225

sector is crucial in order to optimising operational efficiency, ensuring the production of high-quality goods and enhance competitiveness within the manufacturing industry [4-6].

Commonly the manufacturing industry around the world are operates in this three main types of production lines that are fully manual, semi-automated and fully automated [7]. In a fully manual production line, a significant number of employees work with tools to produce finished goods. Figure 1(a) illustrates workers manually making cigarettes on a large scale. On the other hand, Figure 1(b) and 1(c) depict the semi-automated and fully automated production lines, respectively. In semi-automated production lines, human assistance is still required for complex tasks that machines cannot perform. In contrast, fully automated production lines require little to no human assistance, as robots handle all tasks efficiently to produce the goods.

(a) (b) (c)

Fig. 1. Types of production line (a) Fully manual [8] (b) Semi-automation [9] (c) Fully automated [10]

Each type of production line possesses distinct advantages and disadvantages, which significantly influence their utilisation in manufacturing [11]. For instance, a fully manual production line offers a high level of flexibility and adaptability, enabling the production of a variety of products. However, it is susceptible to human error, which can potentially affect productivity and quality control. On the other hand, semi-automated production, which combines manual and automated processes, can mitigate human errors and ensure high product quality. Nevertheless, it still involves human intervention, which may introduce inefficiencies and inconsistencies in the output. In contrast, fully automated production provides enhanced efficiency and precision, resulting in consistent top-quality products without interruptions. However, the implementation and maintenance of such a system can be costly, requiring significant capital investment and skilled technical support.

1.1 Common Types of Production Layout

Based on various literature findings on production layouts in manufacturing industries, it can be concluded that there are four common types of production layouts that have been implement on the manufacturing shop floor, as shown in Figure 2 [12-18]. These layouts consist of process layout, product layout, combination layout and fixed position layout. Each of these types of production layout is implemented depending on the product variety and volume produced by the manufacturing sector.

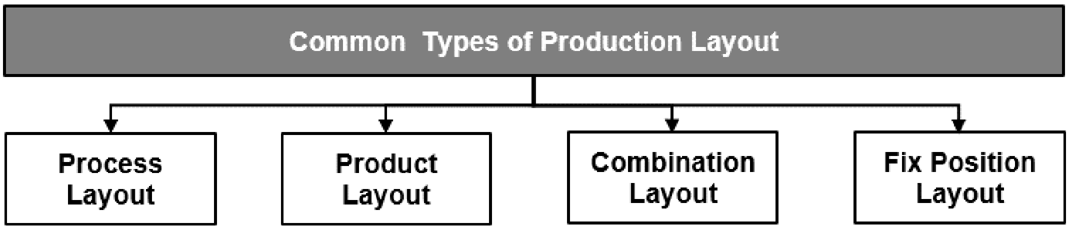


Fig. 2. Common types of production layout

The process layout, also known as a functional layout, is implemented in manufacturing facilities to organize machines, equipment, workstations and materials based on the similarity of their processes. This layout is commonly observed in job-shop production processes, where a wide variety of products with low production volumes are manufactured, such as steel fabrication manufacturing [19]. While process layouts offer flexibility and versatility, they may result in longer lead times and increased material handling.

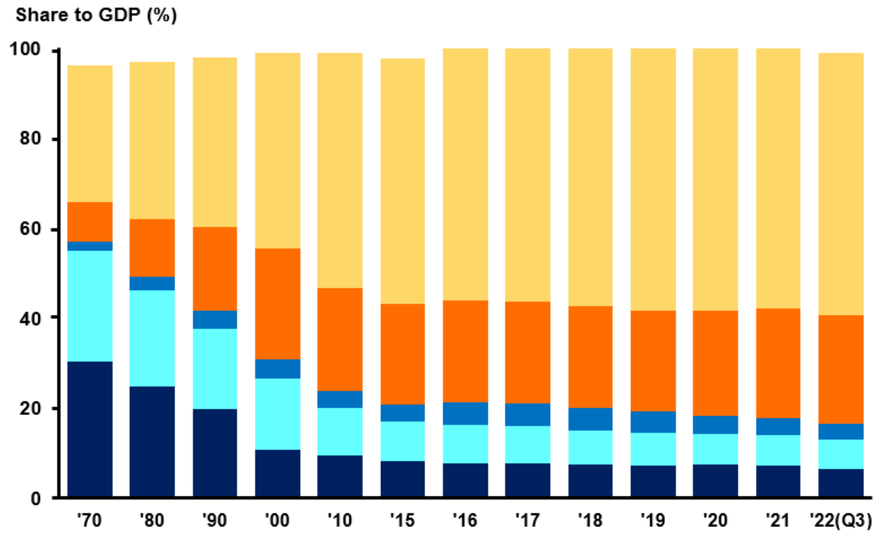
On the other hand, the product layout, also known as a line layout organizes machines, equipment or workstations in a linear sequence or straight line based on the production process. It utilizes conveyor systems to move products from one workstation to another, streamlining the production of high volumes of standardized products with minimal material handling. The product layout is commonly seen in mass production processes, such as automotive manufacturing and food and beverage manufacturing, where a large quantity of identical products is produced [20,21]. Although product layouts offer high efficiency and economies of scale, they may be less flexible compared to other layout types.

The combination layout, also known as a hybrid layout, offers a versatile approach by blending elements from both process layout and product layout. In this layout, machinery and manufacturing equipment are initially arranged in a process layout, but then a group of similar machines is organised in a sequence to produce different types and sizes of products. The main goal of a combination layout is to enhance efficiency, flexibility and productivity. This layout is often used in manufacturing industries that produce a diverse range of products with varying production volumes and specifications, such as electronics assembly manufacturing [22,23].

Conversely, the fixed position layout, also known as a static layout, is employed in manufacturing when the size or bulkiness of the product being manufactured makes it impractical or impossible to move it during the production process. This layout is commonly found in industries producing large and complex products, such as aircraft, ships and heavy machinery [24]. Due to the sheer size and weight of such products, it is unfeasible to move them through a production line or arrange them on a conveyor system.

2. Manufacturing Sector in Malaysia

In Malaysia, the manufacturing sector is a crucial component of the country's economic growth and development [25]. It has consistently been the second-largest contributor to the Gross Domestic Product (GDP) for over the past two decades, as shown in Figure 3. This data was taken from the report "The Malaysian Economy in Figures 2022," prepared by the Ministry of Economy of Malaysia [26].



Year	'70	'80	'90	'00	'10	'15	'16	'17	'18	'19	'20	'21	'22(Q3)
Agriculture	30.5	24.8	19.8	10.9	9.5	8.3	7.7	7.8	7.4	7.2	7.5	7.2	6.6
Mining	24.4	21.4	17.8	15.8	10.6	8.8	8.7	8.3	7.7	7.3	6.9	6.8	6.4
Construction	2.1	3.1	4.2	4.1	3.7	3.7	4.9	5.0	4.9	4.7	4	3.7	3.6
Manufacturing	8.8	12.7	18.6	24.8	22.9	22.3	22.6	22.6	22.6	22.5	23.2	24.6	24.2
Services	30.5	35	37.6	43.3	52.4	54.7	56.1	56.4	57.4	58.3	58.4	57.7	58.1

Fig. 3. Share to GDP by sector in Malaysia (1970-2022) [26]

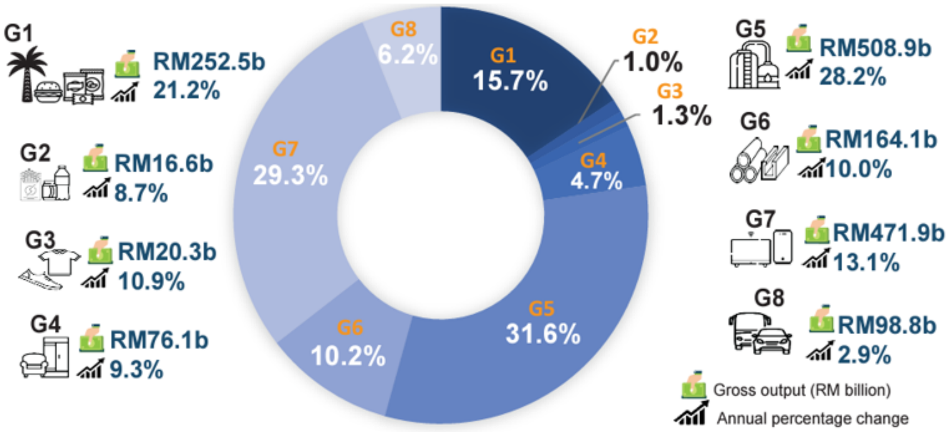
Figure 3 illustrates the share of each sector in Malaysia's GDP from 1970 to the third quarter of 2022. GDP represents the total value of goods and services produced in a country during a specific period and serves as a crucial indicator of the country's economic performance. The sectors included in the table are Agriculture, Mining, Construction, Manufacturing and Services. The data is presented in percentages, indicating the proportion of each sector's contribution to Malaysia's GDP during the respective years. For example, in 1970, the agriculture and mining sectors contributed 30.5% and 24.4% to Malaysia's GDP, respectively. Over the years, there have been shifts in the share of these sectors to the GDP, with gradual declines, reaching 6.6% for agriculture and 6.4% for mining.

On the other hand, the construction sector has contributed less than 5% share to GDP for over five decades, showing no signs of improvement. However, the services sector, which includes industries like finance, retail, education and healthcare, has consistently been the largest contributor to Malaysia's GDP. It has experienced steady growth over the years, increasing from 30.5% in 1970 to 58.1% in the third quarter of 2022. Additionally, Figure 3 highlights the significant growth of the manufacturing sector in Malaysia, which increased its share of GDP from 8.8% in 1970 to 24.8% in 2000, representing a 16% increment. Over the next 22 years, the manufacturing sector consistently maintained a share of GDP above 20%, making it the second-largest contributor to Malaysia's GDP after the services sector.

The robust performance of the Manufacturing sector not only led to increased employment opportunities but also stimulated demand for other industries and influenced international trade and competitiveness [27]. Its consistent presence as a major contributor to GDP demonstrates the sector's resilience and its crucial role in driving economic growth and development in Malaysia. In conclusion, the Services and Manufacturing sectors have been pivotal in shaping Malaysia's economic growth over the years. While the Services sector has been the dominant force, the Manufacturing sector's sustained and substantial share of GDP signifies its significant impact on the country's economic prosperity. Both sectors play a crucial role in driving Malaysia's economy forward and contribute to its overall development and success.

2.1 Malaysia Manufacturing Sub-Sector

Additionally, the manufacturing industries in Malaysia produces various goods, which can be categorised into eight different sub-sectors. These sub-sectors consist of manufacturing that produces goods such as food, beverages, apparel, furniture, chemicals, metal products, electronics, transportation equipment and others, as shown in Figure 4. The data illustrated was obtained from the report "Annual Economic Statistics 2022" from the Department of Statistics Malaysia of the Ministry of Economy [28].



Category	Manufacturing Sub-sector
G1	Food Products
G2	Beverages and Tobacco Products
G3	Textiles, Wearing Apparel, Leather and Footwear Products
G4	Wood Products, Furniture, Paper Products and Printing
G5	Petroleum, Chemical, Rubber and Plastic Products
G6	Non-metallic Mineral Products, Basic Metal and Fabricated Metal Products
G7	Electrical, Electronics and Optical Products
G8	Transport, Equipment, Others Manufacturing and Repair

Fig. 4. Malaysia manufacturing sub-sector gross output [28]

Figure 4 shows the annual gross output of manufacturing industries in 2021, categorised based on its sub-sectors and presented in a doughnut chart format. The doughnut chart illustrates that the petroleum, chemical, rubber and plastics product manufacturing sub-sector (G5) had the highest gross output, amounting to RM 508.9 billion or 31.6% of the total gross output from all sub-sectors. Following closely is the electrical, electronics and optical product manufacturing sub-sector (G7), contributing a total of RM 471.9 billion, representing 29.3% of the total gross output. The third highest gross output is attributed to the food product manufacturing sub-sector (G1), amounting to RM 252.5 billion, constituting 15.7% of the total gross output. These three sub-sectors collectively contribute approximately three-quarters of the total gross output for manufacturing industries in Malaysia. This indicates that they play a crucial role in driving the overall economic output of the manufacturing sector in the country.

The high gross output of G5 and G7 sub-sectors, which are petroleum, chemical, rubber, plastics and electrical, electronics and optical products, respectively, showcases the strong performance of Malaysia's manufacturing industry in these areas. Their significant contributions are likely due to several factors. Firstly, the petroleum, chemical, rubber and plastics sub-sector is driven by the petrochemical industry, which is a major component of Malaysia's economy. The production of petrochemical products and plastics plays a crucial role in various industries, including packaging, construction and automotive. On the other hand, the electrical, electronics and optical products sub-sector is a key driver of Malaysia's manufacturing success. The country has established itself as a major player in the global electronics industry, with a strong presence in semiconductor manufacturing and electrical appliances production. The continuous innovation and export-oriented nature of this sub-sector have contributed to its sustained growth and economic significance.

The food product manufacturing sub-sector, G1, also plays a pivotal role in Malaysia's economy, supplying essential goods domestically and contributing to export revenues. The demand for food products, both locally and internationally, ensures a steady and substantial output for this sub-sector. The implication of these strong-performing sub-sectors is that they provide a solid foundation for Malaysia's manufacturing industry, contributing to economic stability, employment opportunities and international trade competitiveness. The focus on these high-grossing sub-sectors can further boost Malaysia's position as a regional manufacturing hub and attract investment in related industries.

Furthermore, the manufacturing industries in Malaysia can be categorised into two types which are Small and Medium Enterprises (SMEs) and large enterprises. Table 1 provides a summary of the SME definition derived from SME Corporation Malaysia [29-31].

Table 1
SME definition in Malaysia

Category	Criteria	Micro	Small	Medium
Manufacturing	Sales Turnover	<RM 300 000	RM 300 000 – RM 15 million	RM 15 million – RM 50 million
	Employee Count	< 5	5 - 75	75 - 200
Sales & Others	Sales Turnover	<RM 300 000	RM 300 000 – RM 15 million	RM 15 million – RM 50 million
	Employee Count	< 5	5 - 30	30 - 75

According to Table 1, SMEs in the manufacturing sector are defined as companies with a sales turnover below RM 50 million or having fewer than 200 employees. On the other hand, companies with sales turnover exceeding RM 50 million or having more than 200 employees are considered large enterprises. Notable examples of large enterprise manufacturers include Petronas Chemical Group Berhad, Texas Instruments and Nestlé Malaysia, which significantly contribute to the manufacturing sub-sector's gross output. While large enterprises have a significant impact, SME manufacturing also holds substantial importance. Referring to the report of "Micro, Small & Medium Enterprises (MSMEs) Performance 2021" from the Department of Statistics Malaysia highlights that SME manufacturing played a crucial role, contributing one-third of the overall manufacturing share to Malaysia's GDP in 2021, underscoring its importance in the country's economic growth [32].

SMEs are spread across Malaysia, with the top three located in Selangor, Federal Territory of Kuala Lumpur and Johor, as indicated in the "MSMEs Economic Performance Outlook 2021" report by SME Corporation Malaysia [33]. The report also emphasizes that SME manufacturing in Malaysia is predominantly concentrated in sub-sectors G1, G5 and G6. For instance, cosmetic products are one of the examples of SME manufacturing, producing items that fall into sub-sector G5, which is related to chemical products. On the other hand, food-related products such as health supplements, snacks, sauces and others are also manufactured by SMEs and fall into sub-sector G1.

This concludes that currently, most of the SME manufacturing sub-sectors are related to G1 and G5, which necessitates adherence to Good Manufacturing Practice (GMP) guidelines. These guidelines are essential to protect consumers from potential hazards, maintain product efficacy and meet regulatory requirements set by health authorities. Ensuring compliance with GMP guidelines is crucial for the sustainable growth and success of SME manufacturing in Malaysia, as it ensures the safety and quality of products and enhances the reputation and competitiveness of these businesses in the market.

3. A Survey on Current Approach of Malaysia Manufacturing Industries

An online questionnaire using Google Form was conducted in November 2022 to assess the current approach of Malaysia's manufacturing industries, with about 56 participants participating. The questionnaire consists of three different sections designed to gather the following information:

i. Participants' basic information related to their workplace.
ii. Basic information related to the manufacturing types of participants' workplace.
iii. Common issues that occur in the participant’s manufacturing shop floor.

A and B of the questionnaire pertain to gathering basic information about the participants and their workplaces, including details such as their position, department, location, type of product manufactured, production line type and output recording method. In contrast, section C is dedicated to an open-ended question focused on common issues that occur in participant’s manufacturing shop floor. Out of the 56 participants who completed the Google Form questionnaire, 50 of them work in the manufacturing industry in Malaysia. Upon filtering the data, it was found that 82% of the participants hold positions as engineers in their workplaces, while the remaining positions are related to designers, technicians, managers and executives, as shown in Figure 5.

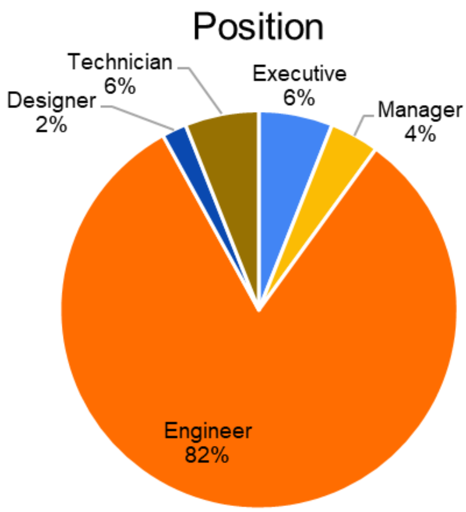


Fig. 5. Participant position in their workplace

In addition, the 82% of engineers from Figure 5 are working in different departments, including manufacturing, test, quality control and quality assurance, maintenance and research and development (R&D). This indicates that the participants have a significant understanding and knowledge related to the manufacturing industries. Figure 6 illustrates the distribution of participants' workplaces across Malaysia, with each state represented by a red colour. The intensity of the red colour indicates the relative strength of the manufacturing industries in each state. The darker shades of red on the map indicate states where manufacturing industries are more prominent, suggesting that a higher number of participants work in this sector in those areas. Conversely, lighter shades of red represent states with a comparatively smaller presence of manufacturing industries.

Fig. 6. Geographic distribution of participant workplaces in Malaysia

From Figure 6, it is evident that two-thirds of the participants' workplaces are located in these three states which are Johor, Penang and Selangor. According to the data from the Annual Statistical Economy report of 2022, these three states are also the top contributors to the manufacturing sector's gross output in Malaysia, with a total gross output of RM 927.5 billion out of RM 1609.3 billion for all states [28]. This indicates that Johor, Penang and Selangor play a crucial role in the manufacturing industry, attracting a substantial number of workers and contributing significantly to the overall economic output of the country. Next, approximately three-quarters of the participants' workplaces are related to the manufacture of electrical, electronics and optical goods, while others are shown in Figure 7.

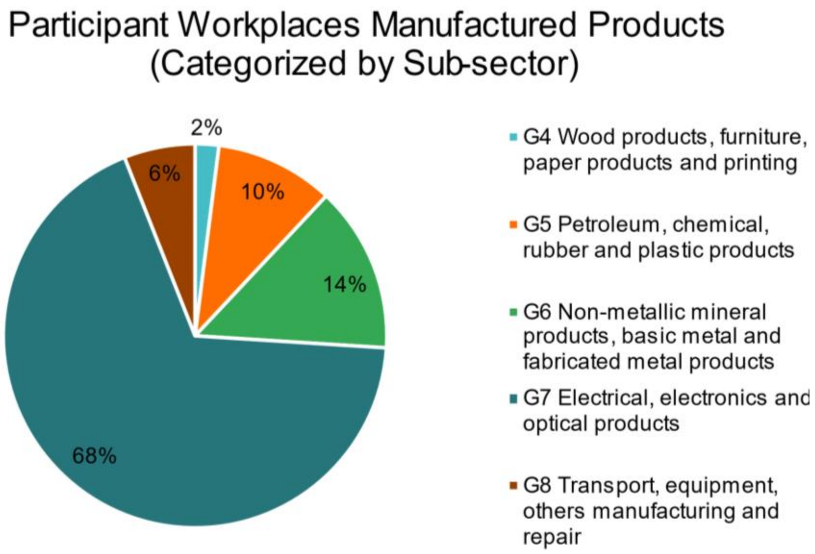


Fig. 7. Participant workplaces manufacture product based on manufacturing sub-sector category

Figure 7 provides a breakdown of participant workplaces based on their respective manufacturing sub-sector categories. Notably, the majority of participant workplaces, accounting for 68%, are involved in the manufacture of electrical, electronics and optical goods (G7), indicating its play a major role in Malaysia's overall manufacturing industry. Moving on to the distribution of participants' workplace production lines and output recording methods, as shown in Figure 8(a) and 8(b), it is found that 80.4% of the participant workplace production lines are operated semi-automatically, 11.8% are operated fully manually and the rest are operated in fully automated operations, as shown in Figure 8. This shows that the current Malaysian manufacturing industry still relies significantly on human labour with the assistance of machinery.

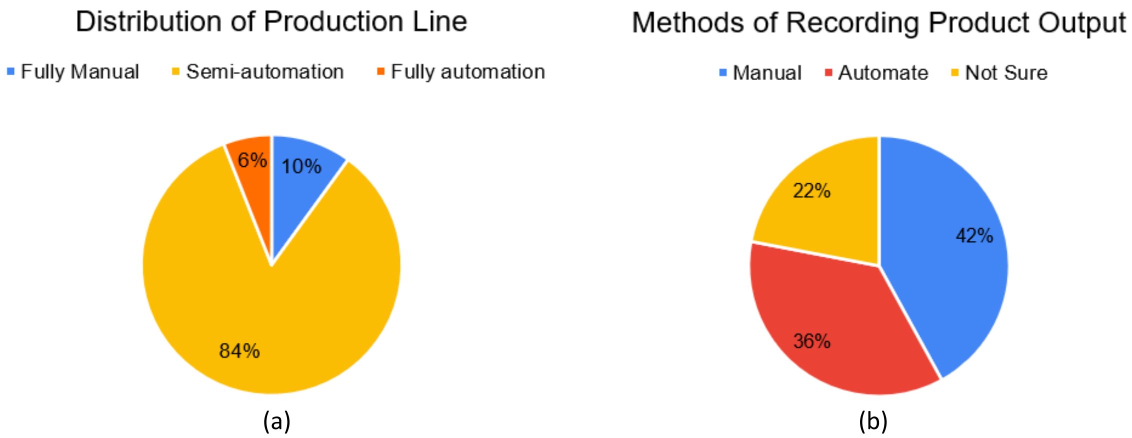


Fig. 8. Participant's workplace (a) Production line approaches and (b) Product output record method

Based on Figure 8(b), the participant workplaces use two different methods, namely automated and manual, to measure or capture the product output. The manual method involves human intervention in recording, while the automatic method relies on machinery or technology for data collection. The data reveals that 43.4% of the participant workplaces utilize the manual method, while 34% use the automatic method. Additionally, 22.6% of the respondents are unsure about the method used. Overall, the results suggest a significant reliance on manual recording methods in the current manufacturing practices.

3.1 Common Issues in Shop Floor of Manufacturing Industries

Continuing to section C of the questionnaire, an open-ended question regarding issues occurring in the shop floor of participants' workplaces was collected and analysed using the thematic coding method. The analysis revealed three distinct types of issues which are human, machine and system issues, as shown in Figure 9. Among these, human issues were the most frequently mentioned, accounting for 48% of the responses, followed by machine issues at 39% and system issues at 13%.

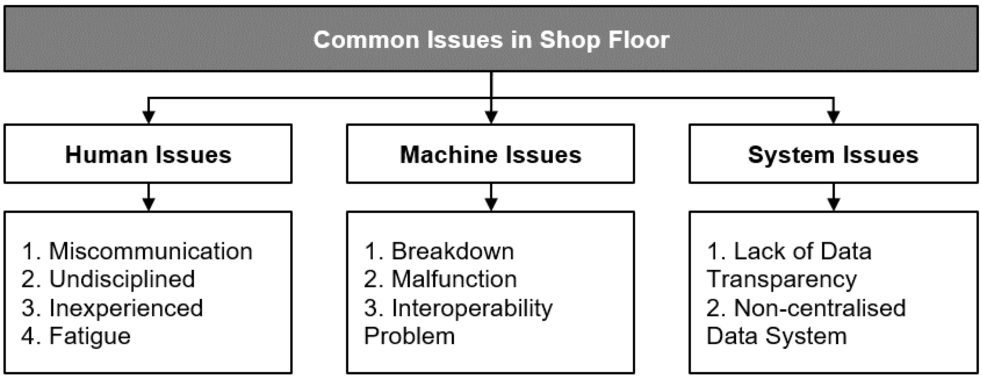


Fig. 9. Common issues in manufacturing shop floor

As shown in Figure 9, human issues are caused by miscommunication, fatigue, lack of discipline and inexperience among workers at the shop floor level. One contributing factor to these human issues is miscommunication between the shop floor and management levels, which leads to frequent occurrences of wrong component parts. Additionally, fatigue resulting from overwork is another significant factor contributing to human issues on the shop floor, resulting in inconsistent product quality and a high rejection rate. Worker discipline is the third factor that leads to human issues on the shop floor. This lack of discipline can cause inefficiencies, delays and potential safety hazards. Furthermore, inexperience among workers can also contribute to human issues due to a lack of adequate training, leading to errors, variations in product output and an overall decrease in production efficiency.

Machine issues are another significant concern on the shop floor, caused by breakdown, malfunction and interoperability problems. The first contributing factor to machine issues is breakdown, which arises from mechanical failures due to inadequate maintenance practices, leading to costly downtime and production interruptions. Additionally, malfunction occurs when machine programs do not follow instructions correctly, resulting in quality issues and a high rejection rate of products. This can have detrimental effects on the overall manufacturing process and product quality. Interoperability problems represent the third machine-related issue on the shop floor. These problems arise from interrupted communication between machines, often caused by network stability issues. The lack of seamless communication can lead to mis operations, further hindering the production process.

The last problem is related to system issue which is due by the system implemented in the manufacturing industry itself that are less effective. This is primarily due to a lack of data transparency and a non-centralized system. The data transparency is compromised by the manual inputting of data into the system by supervisors, making it susceptible to manipulation and inaccuracies. Additionally, the non-centralized system leads to production line stoppages due to material shortages, as data accessibility from other departments is limited, causing delays in the restocking process and disrupting production. Moreover, the non-centralized system necessitates extra meetings between departments to exchange data, resulting in time-consuming activities.

4. Discussion

Based on the survey findings, it is evident that a significant portion of Malaysia's manufacturing industry still relies on human labour, with 80.4% of production lines being operated semi-automatically and 10% fully manually. The current manufacturing technologies also involve manual methods for tasks such as data recording, scheduling and data storage. This reliance on human labour is notable despite the ongoing transition to Industry 4.0, which aims to revolutionize the manufacturing processes through automation and digitalisation. However, this reliance on human labour contributes to inefficiencies in the manufacturing industry, as evident from the common issues mentioned in section 3.1, with approximately half of the issues being related to human factors. Based on the literature findings, it is found that there are several factors that may contribute to the manufacturing industry's continued reliance on human labour in Malaysia [34-36].

One of the major factors contributing to the continued reliance on human labour is the cost of automation. Implementing fully automated production lines requires significant upfront investments in advanced machinery, technologies and systems. This can be a challenge for many small and medium-sized enterprises (SMEs) that make up a significant portion of Malaysia's manufacturing sector, as they may find it difficult to bear such high initial costs [37]. Securing financing for large-scale automation projects can also be a hurdle for these companies [38]. Additionally, limited access to the latest Industry 4.0 technologies can hinder the adoption of full automation. Smaller companies or those in remote areas may face difficulties in accessing and implementing cutting-edge automation technologies, leading them to continue relying on human labour [39].

Another critical aspect is the skill gap and training requirements. Transitioning to a fully automated production environment demands a skilled workforce to operate and maintain the advanced technologies. However, there might be a shortage of workers with expertise in automation and related fields. Upskilling the existing workforce or attracting skilled personnel can be challenging for companies, leading them to stick with human labour.

Moreover, uncertainty about the return on investment from automation can also influence companies' decisions. Some may prefer a cautious approach and initially adopt semi-automated systems to test the waters before fully committing to automation. Additionally, some manufacturing companies may have well-established legacy systems and processes that are difficult to replace or integrate with new automated technologies. Overhauling these systems could require significant time and resources, making semi-automated approaches more appealing.

Despite these challenges, the Malaysian government is actively promoting the adoption of advanced technologies through initiatives like the National Policy on Industry 4.0 and the Industry4WRD program [40,41]. As technology becomes more accessible and a skilled workforce emerges, businesses are likely to realize the benefits of automation and gradually shift towards greater automation and digitalization in the manufacturing industry. This transformation will ultimately enhance efficiency, competitiveness and overall economic growth in Malaysia's manufacturing sector.

5. Conclusion

In conclusion, based on the literature review and survey conducted, it is evident that the manufacturing sector remains crucial to Malaysia's economy. However, many companies still rely on outdated technology and human labour, leading to significant drawbacks in efficiency and productivity on the production line. Despite the advancements in technology, such as Industry 4.0 and intelligent production using robots and artificial intelligence, the current state of the manufacturing industries in Malaysia is still in the process of transitioning towards Industry 4.0, with support from government policies. Therefore, future studies suggested focusing on potential low-cost monitoring and control systems that can help minimize human intervention and improve overall production efficiency.

Acknowledgement
This research was supported by Universiti Tun Hussein Onn Malaysia (UTHM) through Tier 1 (vot Q441).

References

[1] The Editors of Encyclopaedia Britannica, “Manufacturing | Definition, Types, & Facts | Britannica.” (2020). https://www.britannica.com/technology/manufacturing

[2] Esmaeilian, Behzad, Sara Behdad and Ben Wang. "The evolution and future of manufacturing: A review." *Journal of manufacturing systems* 39 (2016): 79-100. https://doi.org/10.1016/j.jmsy.2016.03.001

[3] Aikhuele, Daniel Osezua and Faiz Mohd Turan. "Proposal for a conceptual model for evaluating lean product development performance: a study of LPD enablers in manufacturing companies." In *IOP Conference Series: materials science and engineering*, vol. 114, no. 1, p. 012047. IOP Publishing, 2016. https://doi.org/10.1088/1757-899X/114/1/012047

[4] Turan, Faiz Mohd, Kartina Johan and Nik Hisyamudin Muhd Nor. "Criteria assessment model for sustainable product development." In *IOP Conference Series: Materials Science and Engineering*, vol. 160, no. 1, p. 012004. IOP Publishing, 2016. https://doi.org/10.1088/1757-899X/160/1/012004

[5] Aikhuele, Daniel O., Faiz M. Turan, S. M. Odofin and Richard H. Ansah. "Interval-valued intuitionistic fuzzy TOPSIS-based model for troubleshooting marine diesel engine auxiliary system." *International Journal of Maritime Engineering* 159, no. A1 (2017). https://doi.org/10.3940/rina.ijme.2016.a1.402
[6] Islam, Md Shahidul and Shamsuddin Ahmed. "Work Standardization in Lean Manufacturing for Improvement of Production Line Performance in SME." *Malaysian Journal on Composites Science and Manufacturing* 13, no. 1 (2024): 68-81. https://doi.org/10.37934/mjcsm.13.1.6881
[7] Subramaniam, S. K., A. H. Hamidon and R. S. S. Singh. "Optimization of available resources and methods of capitalizing human capital on industrial process lines efficiently." *Wseas Transactions On Systems* 8, no. 6 (2009): 773-782.
[8] Hoffer, Stef. "Kudus Indonesia April 2017 Female Factory." *Shutterstock*, (2017). https://www.shutterstock.com/video/clip-1008503266-kudus-indonesia---april-2017-female-factory
[9] Weber, Austin. "Lean Plant Layout | 2012-03-01 | Assembly Magazine | ASSEMBLY." *Assembly*, (2012). https://www.assemblymag.com/articles/89823-lean-plant-layout
[10] JR Automation. "Assembly Automation Solutions | JR Automation." *JR Automation*, (2024). https://www.jrautomation.com/capabilities/assembly-solutions
[11] Palomba, Ilaria, Luca Gualtieri, Rafael Rojas, Erwin Rauch, Renato Vidoni and Andrea Ghedin. "Mechatronic re-design of a manual assembly workstation into a collaborative one for wire harness assemblies." *Robotics* 10, no. 1 (2021): 43. https://doi.org/10.3390/robotics10010043
[12] Goldense, Bradford L. "The five types of manufacturing processes." *Machine Design* 87, no. 9 (2015): 88-97.
[13] Grigoriev, S. N., A. A. Kutin and M. V. Turkin. "Modelling complex production processes in aerospace industry based on dimensional analysis." *Procedia CIRP* 7 (2013): 473-478. https://doi.org/10.1016/j.procir.2013.06.018
[14] Di Gregorio, Marianna, Giancarlo Nota, Marco Romano, Monica Sebillo and Giuliana Vitiello. "Designing usable interfaces for the industry 4.0." In *Proceedings of the International Conference on Advanced Visual Interfaces*, pp. 1-9. 2020. https://doi.org/10.1145/3399715.3399861
[15] Bracciotti, M. "Operational Management Study." *Researchgate*, (2017).
[16] Bennett, D. R. and J. El Azhari. "Omni-channel customer experience: An investigation into the use of digital technology in physical stores and its impact on the consumer's decision-making process." In *XXIV AEDEM International Conference*. European Academy of Management and Business Economics (AEDEM), 2015.
[17] Kovács, György and Sebastian Kot. "Facility layout redesign for efficiency improvement and cost reduction." *Journal of Applied Mathematics and Computational Mechanics* 16, no. 1 (2017). https://doi.org/10.17512/jamcm.2017.1.06
[18] Shanmuganathan, Tejasvini and Faizir Ramlie. "Production Line Monitoring using Mahalanobis-Taguchi System in Rubber-Based Product Industry." *Semarak Engineering Journal* 4, no. 1 (2024): 1-17.
[19] Mohamed, NMZ Nik, M. F. F. Ab Rashid, AN Mohd Rose and W. Y. Ting. "Production layout improvement for steel fabrication works." *Journal of Industrial and Intelligent Information* 3, no. 2 (2015). https://doi.org/10.12720/jiii.3.2.133-137
[20] Tahar, Razman Bin Mat and Ali Asghar J. Adham. "Design and analysis of automobiles manufacturing system based on simulation model." *Modern Applied Science* 4, no. 7 (2010): 130. https://doi.org/10.5539/mas.v4n7p130
[21] Veža, Ivica, Nikola Gjeldum and Luka Celent. "Lean manufacturing implementation problems in beverage production systems." *International Journal of Industrial Engineering and Management* 2, no. 1 (2011): 21. https://doi.org/10.24867/IJIEM-2011-1-103
[22] Tarigan, U., A. Ishak, U. P. P. Tarigan, I. Rizkya and B. Mangoloi. "Redesigning production floor layout with process layout and product layout approach in an electronic appliance manufacturing company." In *IOP Conference Series: Materials Science and Engineering*, vol. 1122, no. 1, p. 012058. IOP Publishing, 2021. https://doi.org/10.1088/1757-899X/1122/1/012058
[23] Aikhuele, Daniel Osezua and Faiz Mohd Turan. "A hybrid fuzzy model for lean product development performance measurement." In *IOP Conference Series: Materials Science and Engineering*, vol. 114, no. 1, p. 012048. IOP Publishing, 2016. https://doi.org/10.1088/1757-899X/114/1/012048
[24] Huang, George Q., Y. F. Zhang and P. Y. Jiang. "RFID-based wireless manufacturing for walking-worker assembly islands with fixed-position layouts." *Robotics and Computer-Integrated Manufacturing* 23, no. 4 (2007): 469-477. https://doi.org/10.1016/j.rcim.2006.05.006
[25] Letchumanan, L. Thiruvarasu, Noordin Mohd Yusof, Hamed Gholami and Nor Hasrul Akhmal Bin Ngadiman. "Green Lean Six Sigma: A Review." *Journal of Advanced Research in Technology and Innovation Management* 1, no. 1 (2021): 33-40.
[26] Ministry of Economy of Malaysia. "The Malaysian Economy in Figures," *Official Portal of Ministry of Economy*, (2013). https://www.ekonomi.gov.my/en/socio-economic-statistics/malaysian-economy-figures

[27] Selamat, Siti Norhana, Nik Hisyamudin Muhd Nor, Muhammad Hanif Abdul Rashid, Mohd Fauzi Ahmad, Fariza Mohamad, Mohd Fahrul Hassan, Faiz Mohd Turan, Mohd Zamzuri Mohd Zain, Elmi Abu Bakar and Yokoyama Seiji. "Review of CO2 reduction technologies using mineral carbonation of iron and steel making slag in Malaysia." In *Journal of Physics: Conference Series*, vol. 914, no. 1, p. 012012. IOP Publishing, 2017. https://doi.org/10.1088/1742-6596/914/1/012012

[28] Department of Statistics Malaysia. "Annual Economic Statistics 2022 (Manufacturing)," *Department of Statistics Malaysia*, (2023). www.dosm.gov.my

[29] SMECorp, "Guideline for SME Definition." *SME Corp. Malaysia*, (2020). https://www.smecorp.gov.my/images/pdf/2023/Guideline_on_SME_Definition_Updated_September_2020_Final.pdf

[30] Umar, Azmi and Azizah Hashim. "The mediating role of product and process innovation on the relationship between entrepreneurial competencies and business success in manufacturing companies in Malaysia." In *4th International Conference of Rural Development and Entrepreneurship, Alor Star*. 2017.

[31] Lin, Lee Yee, Khoo Terh Jing, Ha Chin Yee and Lee Ray Re. "Challenges of BIM Software Implementation in Quantity Surveying Consultancy Firms: The Difference Between Large Firms and Small-and-Medium Enterprises (SMEs)." *Journal of Advanced Research in Applied Sciences and Engineering Technology* 34, no. 2 (2023): 169-186. https://doi.org/10.37934/araset.34.2.169186

[32] Department of Statistics Malaysia. "Micro, Small & Medium Enterprises (MSMEs) Performance," *Labour Force Malaysia*, (2021). https://www.dosm.gov.my/portal-main/release-content/micro-small-&-medium-enterprises-msmes-performance-2021

[33] SME Corp. Malaysia. "MSMEs Economic Performance Outlook 2021," *Economic Performance Outlook*, (2021): 50. https://www.smecorp.gov.my/images/Publication/MSME_Insights/ekonomi/EconomicPerformanceOutlook2021-1EnglishFullVersion.pdf

[34] Abdelmajied, FathyElsayed Youssef. "Industry 4.0 and its implications: Concept, opportunities and future directions." In *Supply Chain-Recent Advances and New Perspectives in the Industry 4.0 Era*. IntechOpen, 2022.

[35] Ling, Yong Ma, Nor Aziati Abdul Hamid and Lee Te Chuan. "Is Malaysia ready for Industry 4.0? Issues and challenges in manufacturing industry." *International Journal of Integrated Engineering* 12, no. 7 (2020): 134-150. https://doi.org/10.30880/ijie.2020.12.07.016

[36] Chan, Jin Xuan, Sook-Ling Chua and Lee Kien Foo. "A Two-Stage Classification Chatbot for Suicidal Ideation Detection." In *International Conference on Computer, Information Technology and Intelligent Computing (CITIC 2022)*, pp. 405-412. Atlantis Press, 2022. https://doi.org/10.2991/978-94-6463-094-7_31

[37] Vrchota, Jaroslav, Tomas Volek and Martina Novotná. "Factors introducing Industry 4.0 to SMES." *Social Sciences* 8, no. 5 (2019): 130. https://doi.org/10.3390/socsci8050130

[38] Abdullah, Syahida, Zakirah Othman and Roshayu Mohamad. "Predicting the Risk of SME Loan Repayment using AI Technology-Machine Learning Techniques: A Perspective of Malaysian Financing Institutions." *Journal of Advanced Research in Applied Sciences and Engineering Technology* 31, no. 2 (2023): 320-326. https://doi.org/10.37934/araset.31.2.320326

[39] Hamidi, Saidatul Rahah, Azara Abdul Aziz, Shuhaida Mohammed Shuhidan, Azhar Abdul Aziz and Mudiana Mokhsin. "SMEs maturity model assessment of IR4. 0 digital transformation." In *Proceedings of the 7th International Conference on Kansei Engineering and Emotion Research 2018: KEER 2018, 19-22 March 2018, Kuching, Sarawak, Malaysia*, pp. 721-732. Springer Singapore, 2018. https://doi.org/10.1007/978-981-10-8612-0_75

[40] Unit, Economic Planning. "National fourth industrial revolution (4IR) policy." *Economic Planning Unit, Prime Minister's Department: Putrajaya, Malaysia* (2021).

[41] Ministry of Investment, Trade and Industry of Malaysia. "Industry 4WRD: National Policy on Industry 4.0." *MyGovernment*, (2018). https://www.malaysia.gov.my/portal/content/31224