# Empirical Evidence of AMT Practices and Sustainable Environmental Initiatives in Malaysian Automotive SMEs

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*This paper presents significant empirical evidence on the relationship between Advanced Manufacturing Technology (AMT) practices and sustainable environmental initiatives with the manufacturing capabilities of automotive SMEs in Malaysia. A cross-sectional survey is adopted in this study, which involves 83 Malaysian automotive SMEs. Two hypotheses are proposed in this study, i.e. Hypothesis 1: There are positive effects of AMT practices on the manufacturing capabilities of SMEs and Hypothesis 2: There are positive effects of sustainable environmental initiatives on the manufacturing capabilities of SMEs. The results obtained from the pairwise correlation analysis indicate that both AMT practices and sustainable environmental initiatives have positive effects on manufacturing capabilities, which support both hypotheses. In addition, it is found that 50% of the SMEs implement AMT for flexibility and cost reduction in the past five years. It is also found that more than 80% sustainable practices are adopted in most of the SMEs with the exception of Life Cycle Assessment. Based on the findings, there is a need to move forward into the hybrid approach, which will consider both AMT practices and environmental initiatives to ensure that SMEs remain competitive and become the world player in the automotive industry.*

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## 1. Introduction

The manufacturing industry has significantly strengthened the economic growth in many countries. It is inevitable that the manufacturing industry plays a crucial role in the global economy since it creates goods and services, and serves as a major employment generator worldwide.[1] Nowadays, developing countries invest heavily in the manufacturing sector with economic restructuring. Many companies and factories spring up to meet the production needs of the society especially small and medium enterprises (SMEs), which are a business form consistent with private economics.[2] However, dynamic market conditions as well as the demand for various products based on customer needs result in SMEs having to restructure their production systems in order to respond and adapt to such changes.[3]

Advanced Manufacturing Technology (AMT) plays a major role in improving the quality and flexibility of SMEs. Firms have introduced and implemented AMT since the 1980s in order to gain profits and competitive advantage. Even though the purpose of AMT is to achieve technical capabilities and market profits, the effects of implementing AMT are imperfect.[4]

In Malaysia, SMEs constitute about 84% of manufacturing establishments.[5] In general, SMEs do not only contribute to economic development, but they are also able to sustain themselves as the economy goes through different stages of industrial development. It is believed that SMEs will become even more important as the country develops and will be accorded greater priority in the future. SMEs constantly search for solutions to respond quickly to changes of customers, competitors and technologies, and flexibility plays a critical role in this struggle for success.[6] Flexibility refers to the SMEs' capacity related to changeability, re-configurability and agility of the manufacturing structure, in which the primary aim is to satisfy an increasing variety of customer requirements and address problems associated with costs, time, and organizational disruption and performance losses.[7,8]

Many SMEs must respond to the challenges and requirements of producing competitive goods in order to fulfil customer demands such as deadlines, quality, just-in-time and quantity.

Manufacturers aim at increasing flexibility, timely delivery, and product quality and customer service in order to fulfil customer needs. This in turn, calls for a strategy, which accounts for flexibility, efficiency, quality, reduced production time, increased profits, reduced production costs, increased productivity and regular maintenance services.

One of the systems that is able to respond flexibly is flexible manufacturing systems (FMS). However, the implementation of FMS is an extremely challenging task, which involves a variety of components such as computer numerical controlled (CNC) machines, transportation systems or robots and central computer systems. FMC is considered as the basic component in the development strategies of SMEs and is the key to the survival of the modern manufacturing industry. In recent years, the implementation of flexible manufacturing cells (FMC) is the primary focus of developing countries due to its flexibility and high efficiency up to 90%. However, the implementation and planning of FMC in SMEs play an important role as the key issues need to be addressed in order to increase the utilization of CNC machines and cutting tools.

AMT consists of a potential group of technologies such as computer aided design (CAD), computer aided manufacturing (CAM), computer numerical control (CNC), computer aided process planning (CAPP) and engineering systems, materials resource management, production planning, scheduling, control and integration, material handling systems such as conveyors, automated guided vehicles (AGVs) and robots, FMS/FMC, advanced manufacturing systems such as biology manufacturing systems, factal manufacturing, reconfigurable/ changeable/agile manufacturing systems, sustainable manufacturing systems as well as clean manufacturing systems with electronic data interchange. AMT is a key contributing factor in improving the productivity, flexibility, product quality and green standards (i.e. clean, sustainability and environmental factors) of SMEs. Therefore, SMEs are gaining interest to invest in AMTs in order to attain competitiveness in exporting to potential markets.

However, the decision to invest in AMTs is based on the appropriate support from technical or academic viewpoints as well as from the experience gained by companies that have implemented AMTs. The lessons that can be learnt include the types of AMT, contribution of manufacturing parameters as well as the effects of implementing AMT on the company's performance.[9] Even though profitability is positive, the decision made by SMEs is also dependent on their confidence levels, which is supported by economical parameters such as return on investment.

The increasing human population as well as the need to achieve a high quality of life amplifies the production of goods in the manufacturing industry. Consequently, manufacturing industries need to produce a higher volume of goods to satisfy the demand and deliver good quality products within a shorter time, which requires manufacturing flexibility. One of the strategies that can be used to increase flexibility is new advanced technologies.[10] Kotha and Swamidass[11] also stated that AMT promotes flexibility in manufacturing industries.

On the other hand, stringent legislation on environmental conservation has been the focus of manufacturing industries. According to O'Brien,[12] manufacturers should produce goods that are within the limit of the earth's carrying capacity. It is obvious that manufacturing activities contribute to enormous waste, high resource exploitation as well as excessive energy consumption. Manufacturing dominates industrial energy consumption, and Schipper[13] reported that manufacturing accounts for 84% of energy-related industries' CO2 emissions and 90% industrial energy consumption. This, in turn, has detrimental environmental impact for future generations. It is apparent that manufacturing activities have a significant contribution on environmental impact and therefore substantial improvements through environmental initiatives must be made.

Knowing the importance of AMT and sustainable environmental initiatives in the manufacturing industry, this study is aimed to explore AMT practices and sustainable environmental initiatives currently implemented in automotive manufacturing SMEs within Malaysia. The correlation between AMT practices and environmental initiatives with respect to the SMEs' manufacturing capabilities as an element of competitiveness is also presented in this paper.

## 2. Advanced Manufacturing Technology and Environmental Initiative

The implementation of AMT does not only require substantial investment in technology, but also changes in organizational culture and structure. AMT requires careful planning at all levels of the organization to ensure that its implementation will achieve the desired goals. AMT is a complex process in which various factors need to be considered before the full benefits of AMT can be realized.[14]

It is often stated that the strength of a country lies in the strength of its industrial sector, and progress in an industrial society is accomplished by the development of new technologies. Development is facilitated by the increasing availability of AMT. Small-scale industries (i.e. SMEs) are the backbone of the industrialization process in developing and developed countries and they play a crucial role in increasing the country's economy. With globalization and free trade agreements, SMEs face increasing pressure to adopt AMTs to ensure their survival and remain competitive in the global market. Policy makers use multiple criteria when analyzing complex problems at all levels of the decision-making process in organizations.

Several approaches have been proposed to justify investment in AMTs. AMTs can be categorized into three main groups, namely, economic, strategic and analytical approaches.[15-18]

Even though the economic approach provides ease of data collection and offers an intuitive appeal, this approach only considers a single objective of cash flow and neglects other non-economic benefits such as quality and flexibility. The strategic approach requires less technical data and accounts for the general objectives of the firm. However, it is necessary that strategic approach be coupled with economic or analytic approaches since it is focused on long-term intangible benefits.

The three main elements of AMT are pre-implementation, implementation and post-implementation, which ensures successful implementation of AMT in SMEs. Pre-implementation involves predicting the percentage of the probability of implementation success, selecting robot technologies as well as selecting the suppliers of robot technology. In the implementation phase, managers need to adopt technologies on their existing systems and re-balance the lines. Chen and Small,[19] Ettlie,[20] and Voss[21] studied various companies, which implemented shop floor automation and discovered that top management support, vendor relationships, product-process dependence, employee participation and manufacturing strategy are the key elements of AMT success. Hofmann and Orr[22] studied the average time taken to implement AMT as well as the benefits provided by AMT investments in large German manufacturers. They found that the respondents in their study typically take between 3 and 12 months before making the final decision to invest, irrespective of the department, which generates the idea for AMT and an additional six months to implement AMT.

The adoption of AMT involves a major investment and a high degree of uncertainty and hence, warrants considerable attention within a manufacturing firm at the strategic level.[16] Sambasivarao and Deshmukh; Small and Chen; Chan et al.; Sohal et al.[23-26] identified that there are several barriers faced by manufacturers, which may hinder the successful adoption of AMT. Consequently, issues involving selection and justification procedures assume greater importance.

Studies conducted in the past two decades have shown that the benefits of AMTs are both tangible and intangible and they are hinged on the types of AMT and their applications.[21,26] According to Sambasivarao and Deshmukh,[23] AMTs involve a set of quantifiable and non-quantifiable attributes and therefore there is a need to evolve an integrated framework for a comprehensive appraisal of AMTs using these attributes. There is little doubt that significant tangible and intangible benefits can be gained from implementing AMT and failure to quantify all benefits is detrimental to the decision-making process, regardless whether the project is accepted or rejected.[24]

Alvarado[27] conducted a survey on 189 cases in Juarez City, Chihuahua, Mexico, to identify the problems in the implementation of AMTs. The results showed that the main problems, which need to be addressed, are related to maintenance, special installations, suppliers that are far away, in accomplishment of production standards, lack of economic resources, fear of risk to invest and custom problems.

The literature on AMT justification shows that the idea of a strategic, non-monetary decision process has been consolidated.[28-30] Over the last 10 years, many authors proposed that financial and cost indicators should be complemented by non-financial measurement tests related to qualification, delivery and flexibility of AMT performance measurement systems, in which the integration of various business areas are encouraged and the management's strategic objectives are reflected.[31] In addition, it is dangerous to solely focus on costs when monitoring the results of investments made in AMT as it is possible that the system used to assess performance may lead to managers ignoring other strategic objectives.[32] According to Small[18] while costs (hardware, software, planning, training, operations, etc.) as well as operational benefits are easily quantifiable, some of the major strategic benefits are difficult to estimate. The use of strategic justification approaches have been proposed in order to overcome this limitation, whereby comparison with competitors, retention, attainment or perception of industrial leadership and expected future developments in the industry are considered.

Environmental initiatives indicate that environmental practices and regulations stated by governments are the main sustainability drivers in recent years. Companies are required to comply with these environmental practices and regulations or their reputation will be tarnished. Since the early 1990s, environmental conservation has become an increasingly important area in the academia.[33-35] Sharma and Vredenburg[36] identified that there are three capabilities obtained from proactive environmental practices, namely, capability of mitigating regulation pressures, integration capability and capability for continuous innovation. Klassen and Whybark[37] studied the impact of environmental technology on manufacturing performance and concluded that more typical proactive environmental initiatives such as prevention technologies have a positive effect on manufacturing performance. González-Benito and González-Benito[38] found that there is a positive relationship between the company's environmental initiatives and competitiveness. Zhu[39] investigated environmental initiatives of various manufacturing, industrial sectors in China and presented the links between these initiatives and performance outcomes.

In addition, manufacturing firms have focused on the significance of environmental practices as a part of the broader scenario of sustainability in recent years. The sustainable development concept emphasizes those developmental activities including manufacturing must ensure that the present needs are delivered without compromising environmental aspects for future generations. In fact, the scarcity of natural resources, depletion of fossil fuels, global warming and other environmental issues have garnered global attention to integrate environmental conservation into their practices. Sustainable manufacturing is one of the environmental initiatives, which will reduce environmental impact during manufacturing activities by implementing waste minimization, resource efficiency, pollution prevention, energy-awareness manufacturing processes, end-of-life management and many more.

A burgeoning amount of research have been focused on the effects of environmental considerations on the firms' performance.[40-42] Bey[43] identified the drivers and barriers in the implementation of environmental strategies in manufacturing companies. Hofer[44] investigated the competitive determinants of environmental management in US manufacturing firms. Schoenherr[45] examined specific strategies for sustainable business development, explicated the role of environmental programmes and initiatives on relative competitive performance along the dimensions of quality, delivery, flexibility, and cost through an extensive survey in various countries. Joung[46] categorized the indicators into five dimensions of sustainability, namely, environmental stewardship, economic growth, social well-being, technological advancement and performance management in order to assess a company's manufacturing operations. Ilgin and Gupta[40] presented an evaluation of environmentally conscious manufacturing and product recovery and they provided a state of the art survey of published works. They classified over 540 published references into four major categories, i.e., environmentally conscious product design, reverse and closed-loop supply chains, remanufacturing, and disassembly. Schrettle[47] described how the decisions of sustainability moves are motivated and which dimensions in the firm are affected by these moves. First, they operationalized sustainability challenge by defining the relevant drivers of sustainability. They developed a framework, which shows the dimensions that affect decisions concerning sustainable move and the dimensions that are affected by these decisions.

There is a growing consensus that hybrid investment approaches, which include both strategic and economic justification criteria are needed to, evaluate these complex systems. Thus, there is a need to investigate hybrid approaches based on empirical evidence.

## 3. Conceptual Framework and Research Propositions

In this study, the conceptual framework is based on the foundation that AMT and environmental initiatives are the initial phase, which will influence the manufacturing capabilities of companies. It is proposed that the adoption of AMT and environmental initiatives are linked to manufacturing parameters, which further affects the firms' performance. The exploitation of AMT and environmental initiatives is expected to generate new manufacturing capabilities, which will improve the companies' performance by improving manufacturing parameters. It is suggested that the success of implementing AMT and environmental initiatives will facilitate the companies by remaining competitive in the market. The conceptual relationship between AMT, environmental initiatives, manufacturing parameters and companies' performance is illustrated in Fig. 1.

The current implementation of AMT and environmental initiatives in companies will be examined based on survey and industrial visits in order to obtain an insight on the implementation of AMT and manifestation of environmental productivity. In addition, the integration of environmental initiatives on the selection of materials and processes in the manufacturing systems will be identified. The following hypotheses are proposed based on the conceptual framework and theoretical perspective of AMT and environmental initiatives:

Hypothesis 1: There are positive effects of AMT practices on the manufacturing capabilities of SMEs.

For the first hypothesis, the current types of AMT will be identified, which include the motivation and trends in selecting a specific AMT. Based on the information provided, the impact of AMT implementation on the manufacturing capabilities of SMEs will be investigated. The manufacturing parameters, which significantly contribute to the manufacturing capabilities of SMEs, will be determined in order to gain an understanding on profitability performance.

Hypothesis 2: There are positive effects of environmental initiatives on the manufacturing capabilities of SMEs.

The concept of environmental initiatives and productivity will be reviewed and the most representative environmental management practices will be determined. The relationship between environmental productivity and initiatives with the companies' operation will be determined. The investigation includes measures of the companies' manufacturing capabilities in relation to environmental initiatives. The direct and indirect effects of environmental productivity on the companies' manufacturing capabilities will be investigated in this study.

## 4. Methodology

A cross-sectional survey was selected in this study, in which two questionnaires were prepared based on the literature and conceptual

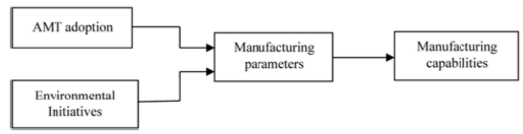


Fig. 1 Conceptual Framework

framework. The first questionnaire was prepared to obtain an insight on the profiles of automotive manufacturers in Malaysia. The second questionnaire was prepared to gain an understanding of the AMT practices and environmental initiatives in Malaysian automotive SMEs. A total of 367 automotive manufacturers, which fabricate metal-based products were retrieved from the Automobile Association, SMECorp database as well as Internet search. The data were collected via email surveys, industrial workshops, and industrial visits. The respondents for the survey were selected from those whose job designation is in the middle and top management such as Chief Executive Officers, General Managers, Production Managers or company owners to ensure that the questionnaires were addressed to the appropriate target audience. A total of 83 companies responded to the first questionnaire whereas 16 companies were selected specifically for industrial visits.[48] The second questionnaire was distributed during the industrial visits. The questions were all adapted from published works, and revisions were made by university professors and academic scholars in terms of content and the logic of questionnaire design.[49]

### 4.1 Survey instruments

#### 4.1.1 AMT practices and environmental initiatives

Each respondent was requested to score the degree of AMT implementation and environmental initiatives practiced in his/her company based on 'use', 'consider to use' and 'not use' for various types of AMT. The various types of AMT listed in the questionnaire are shown in Table 1.[50] The degree of implementation for each environmental initiative practices is shown in Table 2.[51]

#### 4.1.2 Manufacturing capabilities

The manufacturing capabilities were measured about four aspects adapted from Spanos and Voudouris[52] namely, flexibility, product quality, innovation and cost reduction. The respondents were specifically requested to score the manufacturing capabilities using a five-point Likert scale (1: 'Very Low', 2: 'Low', 3: 'Fair', 4: 'High' and 5: 'Very High'). Each capability objective has a few items and therefore principal component analysis is employed to extract the items.

### 4.2 Data analysis

Reliability test was used to measure inter-item consistency by calculating Cronbach's alpha. A value above 0.70 indicates that the measure is reliable. Factor analysis was also used to categorize the items in the questionnaire into the desired categories. Multiple regression analysis was conducted to test the hypotheses proposed in this study. The manufacturing capabilities were interpreted as dependent variables, whereas the independent variables were reflected by AMT practices and environmental initiatives. Three control dimensions were considered for the group of independent variables:

Table 1 Types of AMT and environmental initiative, practices

| Type of AMT | Type environmental initiative, practices |
|---|---|
| Computer Aided Design (CAD) | Adhere to standards and regulations |
| Computer Aided Engineering (CAE) | Lean Production |
| Computer Aided Process Plannng (CAPP) | Life Cycle Assessment (LCA) |
| Computer Numerical Control (DNC) | Emission reduction |
| Robotics (RO) | Environmental Management System (EMS) |
| Group Technology (GT) | Energy saving |
| Flexible Manufacturing System (FMS) | Material Efficiency |
| Automated Material Handling Systems (AMHS) | Product recovery (recycling, reuse, re-manufacturing) |
| Automated Guided Vehicles (AGVs) | |
| Bar Coding (BC) | |
| Radio Frequency Identification (RFID) | |
| Automated Retrieval System (AS/RS) | |
| Decision Support System (DSS) | |
| Optimization Tool | |

Table 2 Manufacturing capabilities and measures

| Capabilities | Measures |
|---|---|
| Flexibility | Batch size changeability<br>Location restruction<br>Large number of product variants |
| Product Quality | Stable product quality<br>Ability to deliver demanding product specifications |
| Innovation | Speed in producing a product<br>Frequency of changing technology |
| Cost Reduction | Deliver low cost production<br>Energy saving |

1. Company size
2. Production type
3. Type of operation system

The gamma correlation coefficient was used to determine if there are significant differences between AMT users and non-AMT users in terms of the manufacturing capabilities. In general, the gamma correlation coefficient is used to study the association between two given sets of data in a survey using Likert scale or ranked items.[53] If the data are not ranked and are normally distributed, parametric tests such as t-test and analysis of variance (ANOVA) can be used. The methodology adopted in this study is shown in Fig. 2.

## 5. Results, Analysis and Discussion

### 5.1. Descriptive analysis

A total of 367 questionnaires were e-mailed to the respondents from a total of 412 automotive industries and 83 questionnaires were returned. A summary of survey respondents is given in Table 3 and the companies' engagement with AMT and environmental initiatives is shown in Table 4.

### 5.2 Interpretation results

The second phase of this study involves industrial visits to 16 automotive SMEs who have agreed to participate in this phase. The second questionnaire was distributed during these visits to obtain data for hypothesis testing. The results are summarized in Table 5.

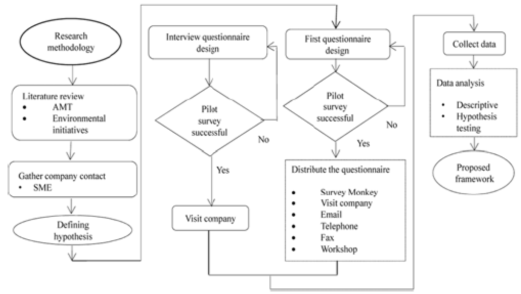


Fig. 2 Flowchart of methodology

Table 3 Summary of survey respondents

| Statement | Yes | No | No response |
|---|---|---|---|
| Do you incorporate environmental aspects during the manufacturing process? | 64% | 6% | 30% |
| Has your company initiated any sustainable manufacturing practices? | 71% | 10% | 19% |

The frequency of product types is shown in Table 5. Five companies from a total of 16 did not reply with regards to processor type. From the 11 feedback received, only five companies use machining process whereas the other companies use assembly process. Six companies from a total of 16 did not respond with respect to the number of facilities. From the 10 feedback received, four companies were categorized as medium-sized in which the number of facilities are between 7 to 15, whereas six companies were categorized as large-sized in which number of facilities are greater than 15). It was found from this survey that there are no small companies based on the number of facilities. Three from a total of 16 companies did not reply with regards to material handling methods. From the 13 feedback received, it was found that only one company uses AGV, whereas eight companies use robots for material handling. Seven companies from a total of 16 did not respond with respect to processing time. From the feedback received, only one company has a processing time, which exceeds 1 hour. Five companies from a total of 16 did not reply with regards to machine dimension. It was found that only two companies do not have large machines (dimension: $1\times1$ $m^2$).

The frequency distribution of AMT implementation is shown in Fig. 3.

It can be observe that all companies are implementing CAD at present and none of these companies implement RFID or AS/RS. This strongly suggests that factor analysis should be conducted for the AMT items, which will be discussed in Section 5.3.

The frequencies of sustainable practices by SMEs are shown in Fig. 4. It can be seen that approximately 90% of the companies do not implement LCA whereas more than 65% implement the regulation, lean production, emission, EMS, energy saving, material efficiency and recovery.

The frequency of responses for manufacturing capabilities over the past five years is given in Fig. 5.

The statistics summary confirms that most of the respondents

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