Drivers and Barriers of Advanced Manufacturing Technology Implementation in Saudi Arabia

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Abstract: The purpose of this paper is to present a systematic literature review to identify opportunities and challenges that face Advanced Manufacturing Technology (AMT) adoption in Saudi industrial sector. It also highlights the critical factors behind those opportunities and challenges, which need to be taken into consideration when it comes to AMT implementation. This study uses a systematic review of the literature contained in the two databases ProQuest, and Compendex and on the search engine Google Scholar. Moreover, the study highlights a gap in the research efforts for identifying the need for effective integration and interaction between the eight different categories mentioned previously for both developed and developing economies. For that reason, it is recommended that researchers adopt a broader view that includes the role of integration and interaction between critical factors in each category and their impact on AMT adoption. The systematic literature review in this study used to review all vital elements of adopting AMT and identifies new research avenues and different approaches to implementing AMT, focusing on the integration between the different categories that can be used for AMT adoption in Saudi Arabia.

Keywords: Advanced Manufacturing Technology, Systematic literature review, implementation, Adoption, Drivers, Barriers, Success Factors, Challenges, Saudi Arabia.

1. INTRODUCTION

The industrial transformation in any country can be driven by adopting advanced manufacturing technologies so, and it is more practical to consider AMT adoption as an engine of any industrial change. The critical factors which have an impact over AMT adoption in one area of the industry also can be the same in any other areas that rely on technology to run that industry. From a more comprehensive view of the topic, AMT adoption is related to the rapid growth of technology. It can be considered as an umbrella that contains a variety of different types of manufacturing and industry applications underneath it.

Lately, the Saudi government lunch its strategic vision for the year 2030. According to the vision official document, the Saudi government is preparing itself for massive industrial transformation. The national industrial development and logistic program of the vision 2030, is considering the development of the industrial sector to be somehow risky because of the uncertainties associated with the AMT that can be implemented to achieve that goal. For that reason, research efforts should be more focused toward uncovering those uncertainties by determining the drivers and barriers of AMT adoption in the country.

2. REVIEW OF THE PREVIOUS STUDIES

Most of the earlier studies covered in this literature review focus on AMT from different dimensions. These dimensions represent the boundaries that every country should take into consideration to adopt AMT successfully. The proposed classifying of aspects in this study are planning, management, business,

technical, economy, society, policy, and environment. The following part will discuss each one of the eight dimensions.

2.1. Planning for Implementation

Planning for appropriate adoption of advance manufacturing technology is a challenging matter. Adequate planning would pave the road into the successful implementation of advanced manufacturing technology. Regardless of the manufacturing applications and to which area they belong to, the planning efforts would lighten the path toward desired results and outcomes in addition to uncover any ambiguities and uncertainties (Chen and Small 1996). With focusing on competitiveness, many firms or organizations would give the planning stage the highest priority throughout any AMT project's life cycle. Planning for AMT adoption include four main stages, which are; strategic planning, justification; training and installation; and implementation (Chan, Chan et al. 2001).

Planning efforts toward the appropriate installation of the technology are critical matter because it determines the actual utilization of the technology (Small 2007). Planning activities must consider giving enough room for innovation. While putting plans in place, the innovation part is mainly concerned with the impact of AMT diffusion and transfer, in addition to concentrating on the effective adoption of the technology (Rhodes and Wield 1994). The ability to make a positive change in different aspect is also a critical role in the planning process where the direction of the shift determined according to desired outcomes and results (Small 2007).

2.2. Managing the implementation

Management approaches are playing a critical role in the adoption of advanced manufacturing technology. Management experience and knowledge about AMT are crucial factors for successful adoption and implementation (Chan, Yusuff et al. 2015). In addition to that, having a clear picture, and foresight of the AMT history and future can be considered as a strong point for any effective management practices. It is possible to say that any successful implementation of AMT requires firms and organizations to have a workforce with a higher level of qualifications and skills in addition to a flexible organizational structure that supports and induce the changing process (Yu, Shen et al. 2011).

The main focus of any management approach, which is designated to assure a successful implementation of AMT, is the change process. It is commonly known that there is a high risk on any transformation efforts desired by any firm or organization unless there is an awareness of the requirements to make that transformation less risky. Furthermore, the changing process which is used for the adoption of AMT requires appropriate changes in the firm's and organization's structure and infrastructure in addition to keeping up with performance enhancements to improve the capability (Saberi, Yusuff et al. 2010). Furthermore, When a firm or organization decides to adopt or implement AMT then, it becomes crucial to evaluate the feasibility of changing process. Moreover, it should know the situations in which it is preferable to current manufacturing systems (Beatty 1992).

2.3. The Business behind AMT Adoption

From a business perspective, utilization of AMT is considered as a critical factor which helps manufacturing firms around the world to reduce manufacturing costs, improve the quality of their products, increase the desired outcomes as well as production flexibility, in addition, to help with maintaining and enhancing their competitiveness on global markets (Hynek, Janeček et al. 2009). One of the main concerns when it comes to AMT adoption and implementations in return on investment. Firms are mainly focusing on the amount of money they can make when applying new manufacturing technology with makes AMT grows very fast in the last couple of decades in addition to the stability and growth of the technology itself (Chung 1991). However, other firms are finding themselves forced to adopt AMT because of the competitiveness pressure they face in a specific market (Percival 2009).

Generally speaking, it is possible to say that implementing a competent AMT can be considered as a key to enter a new market segment or to maintain a share of the current market. In addition to that, AMT offers an opportunity for firms to gain a competitive advantage to make them sustainable over a long-term timeframe (Sohal 1997). Moreover, at the heart of this technology-driven manufacturing lie the necessities of competition and scarcity of resources. However, not only are companies always under pressure to produce more with less but, at the same time, make things better and bring them to market faster than their competitors (Khan and Nasser 2016).

2.4. The Need For Technical Capability

There is always a kind of healthy relationship between firms' performance and their technical abilities. In most cases, higher performance is driven by high technological capacity which leads firms to maintain its performance at a high level or keep increasing their technical capabilities through joint ventures or licensing agreements (Singh and Khamba 2008). During the selecting phase of AMT adoption, it is necessary to specify what the new technology is capable of and wither the firm's worker are capable of dealing with it or not. In other words, the management is encouraged to answers some questions regarding the technical requirements of the adopted AMT (Bessant 1985). It is also a critical matter to assesses the technical capabilities of the technology itself and the firm workforce and how the two parts should react.

The technical strategy has to cover every technical process aspect of the implementation and at the same time, determine the technical requirements for adoption of the AMT (Dawson 1996). However, some firms and companies have a kind of similar strategy which is called utilization strategy, and the only difference is that some utilization strategy doesn't include a clear role for the firm's workforce (Chung and Swink 2009). So, it is necessary to have the human efforts involved in the technical strategy to avoid any conflict between the workforce and the technology (Co, Eddy Patuwo et al. 1998).

2.5. The Economic Side Of AMT Adoption

As an essential source of income for any national economy, the industrial sector cannot achieve any success on its own without relying on other sectors in the country. There has to be some kind of harmonious relationship of shared interests between industry and other leading sectors of the national economy. Moreover, the development of an industrial sector might be a result of the development of other sectors (Dawson 1996). Also, the development of the industrial sector might lead to the development of other sectors. Adopting AMT as an engine for industrial development would be a wise decision because of the enormous benefits that national economy gains from this process (Sharma, Dangayach et al. 2008)

2.6. Social Impact Of AMT Implementation

The social part which covered in previous studies considered as a practical contribution which used to determine how the society reacts towards AMT adoption. Highlighting the human factor impact on AMT adoption is essential to develop an effective implementation strategy for AMT (Co, Eddy Patuwo et al. 1998). Most of the studies that cover the social part of the topic have linked social awareness to the performance of any organization that adopts AMT, where high social awareness leads to high performance and vice versa (Chung 1996). Furthermore, cultural barriers are playing an essential role in adopting any new technology and should be dealt with carefully when considering the social aspect of any implementation efforts (Majchrzak 1988)

2.7. Polices And Regulations Associated With AMT Adoption

Adopting new technologies for manufacturing purposes could be a challenging issue when there are no policies or regulations to organize every aspect of the matter. Policies formulation is a critical step of AMT adoption, which might determine the capability of an organization to achieve successful implementation of the technology (Park 2000). Moreover, the flexibility of these policies and regulations should be taken into

consideration to make considerable space for any innovation efforts (Small and Yasin 1997). Also, it is necessary to make continuous evaluation and updates to these policies based on the feedback process.

2.8. Environmental Awareness Of AMT Implementation

Taking environmental precaution when adopting AMT is not a luxurious matter anymore, but rather a necessity. Noticing how the industry has negatively impacted the environment throughout the years makes it an ethical role for any decision-maker to consider environmental impact when deciding which AMT to adopt (Szalavetz 2017). So, with high environmental awareness from all stakeholders affected by the AMT, it is possible to adopt an environment-friendly AMT.

3. PROPOSED METHODOLOGY

This study consists of a systematic review of the literature, which is quite an innovative method in the social sciences and not frequently used in AMT studies. Furthermore, this study uses a systematic review of the researches contained in the two databases ProQuest, and Compendex and on the search engine Google Scholar by using keywords search to enhance the overall quality of the review by minimizing bias which included in all published research. The following table shows the different search phases.

Table 1: Systematic review search, keywords, and results

Search Phase	ProQuest	Compendex	Google Scholar	Total
All articles containing at least one of the following keywords in their abstract or title: AMT AND EV AMT AND Success factors AMT AND Challenges AMT AND Barriers AMT AND Adoption AMT AND Implementation AMT AND Saudi Arabia	1,282	864	1,822	3,968
All articles containing at least one of additional keywords in their abstract or title: Country, economy, firm; company; organization	417	327	746	1,490
All articles whose abstract content was substantively relevant (fit for purpose)	122	184	231	537
All articles whose text was effectively relevant (fit for purpose)	41	33	19	93

To decide which article can describe as “Fit for Purpose”, the literature searching process conducted according to the following Eligibility Criteria.

Table 2: Eligibility criteria

Inclusion	Exclusion
• English language • Peer-reviewed papers, book chapters, official governmental reports, thesis and dissertations. • Cover one or more of the previously mentioned dimensions. • From 1985 until now.	• Other languages • Conference papers • Cover aspect other than the eight dimensions. • Earlier than 1985

Moreover, about %61 of the studies contained in the literature review used questionaries and structural equation modelling as a methodology. Other studies used other quantitative and qualitative methodologies, such as interviews and case studies. Based on that, it is possible to say that questionaries and structural equation modelling considered as an appropriate type of methodology used in studies concerning AMT adoption.

By conducting a systematic literature review on the previous studies, it becomes evident that the main stakeholders of AMT adoption in most economies are; Government, Private Sectors, Academia, and Society. Understanding the interactions between the stakeholders will undoubtedly pave the road for successful AMT adoption in different types of industry (Löfsten and Lindelöf 2002). The following figure highlight the stakeholders of AMT adoption.

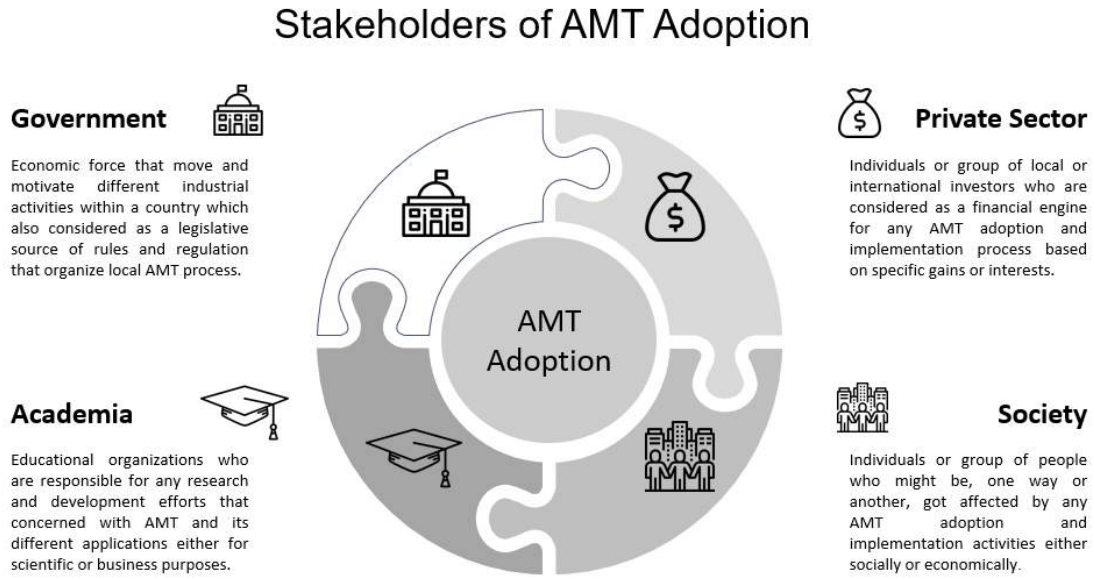


Figure 1: Stakeholders of AMT adoption

Eight different dimensions of the AMT implementation were used to group and categorize the critical factors that have an impact on the adoption of the AMT. These factors can be considered as both opportunities and challenges to the adoption and implementation process. If the firm gets benefits from these factors to adopt and implement AMT, then, those factors can be described as drivers; otherwise, they will be considered as barriers. The following table shows the different dimensions and each critical factor related to them.

Table 3: Dimensions and critical factors that impact AMT adoption

Dimension	Critical Factor	Articles
Planning	Long term strategy Consistency	(Chen and Small 1994), (Chen and Small 1996), (Efstathiades, Tassou et al. 2002), (Millen and Sohal 1998), (Small 2007), and (Sohal 1997)
Management	Support and motivation Management commitment Flexibility Research & development Information systems	(Beatty 1992), (Hottenstein and Dean Jr 1992), (Hynek, Janeček et al. 2009), (Zammuto and O'Connor 1992), (Gupta, Chen et al. 1997), (Beaumont, Schroder et al. 2002), (Leonard-Barton and Deschamps 1988), (lo Storto 2018), (McDermott and Stock 1999), and (Pao-Long and Lung 2002)
Business	Investment Cost Marketing Business capabilities Capital availability	(Khan and Nasser 2016), (El-Tamimi 2010), (Chan, Chan et al. 2001), (Putterill, Maguire et al. 1996), (Tesar 1995), and (Löfsten and Lindelöf 2002)
Technical	Technical capability Manufacturing capabilities Training Expertise Quality	(Kumar, Singh et al. 2018), (Bessant 1985), (Singh and Khamba 2009), (Udo and Ehie 1996), (Chang and Wang 2009), and (Singh and Khamba 2010)
Economy	Resources Ecosystem Infrastructure Government support	(Agyemang, Kusi-Sarpong et al. 2019), (Lyu and Gunasekaran 1993), (Zhao and Co 1997), (Eid 2009), (Sharma, Dangayach et al. 2008), and (du Preez and De Beer 2015)
Policy	Laws and Regulations Governmental agencies support	(Small and Yasin 1997), (Park 2000), and (Löfsten and Lindelöf 2002)
Society	Qualified HR Adequate training Relationship Communication Supplier Support Resistance	(Chung 1996), (Co, Eddy Patuwo et al. 1998), (Majchrzak 1988), (Siegel, Waldman et al. 1997), (Abd Rahman and Bennett 2009), and (Shani, Grant et al. 1992)
Environment	Environmental awareness	(Szalavetz 2017)

It would be possible to develop an algorithm using previously mentioned critical factors, which can be used to identify different drivers and barriers. For that purpose, a questionary can be constructed to measure the responses of the stakeholders toward the critical factors. Furthermore, analyzing these responses can be used to categories each vital element to be either a driver or a barrier. The following figure shows the drivers and barriers algorithm.

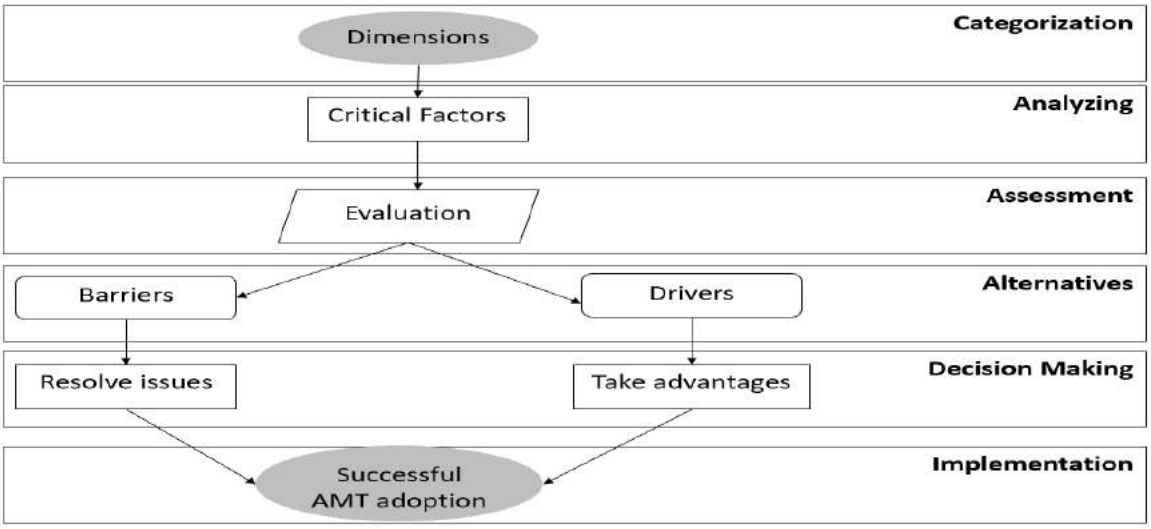
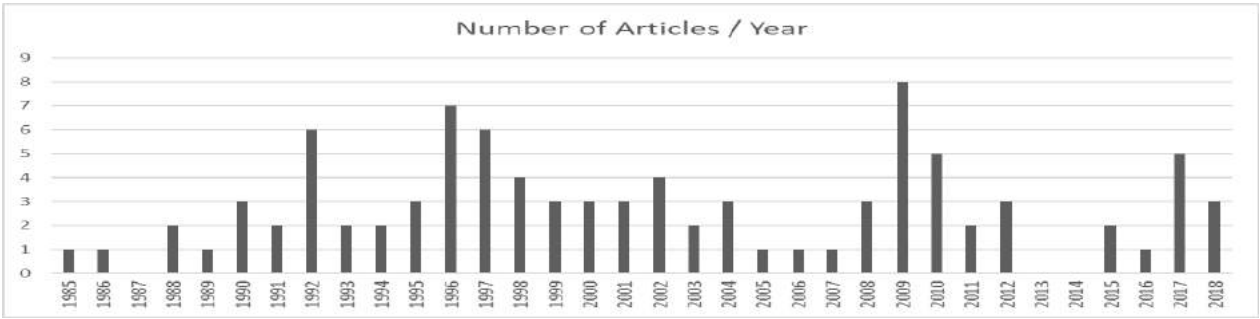


Figure 2: Drivers and barriers algorithm

4. RESULTS AND DISCUSSION

4.1. Articles Timeframe And Categories

This systematic literature review analyzed a total of 93 articles that were published from 1985 to 2018 and are non-uniformly distributed in time, as shown in the following graph.



Graph 1: Temporal distribution of articles selected for the literature review

It is noticeable that the last eight years have a smaller number of articles compared to other previous periods. The number of articles at a specific time might vary according to different circumstances, such as the dominant manufacturing technology of each period. In order to come up with a specific description for the published articles, the dimensional grouping of the articles was used to determine which type of articles were published each year.

Table 4: Temporal distribution of categorizing articles selected for the literature review

Year	Management	Planning	Technical	Business	Economy	Social	Policy	Environment	Mix	Total
1985			1							1
1986		1								1
1987										0
1988	1					1				2
1989						1				1
1990		1				1			1	3
1991	1			1						2
1992	3	2				1				6
1993	1				1					2
1994	1	1								2
1995		1		1					1	3
1996		1	1	1	1	2			1	7
1997	1	2			1	1	1			6
1998	1	1				2				4
1999	3									3
2000	1		1				1			3
2001	1			2						3
2002	3	1								4
2003	1	1								2
2004	1			1		1				3
2005					1					1
2006		1								1
2007	1									1
2008		1	1		1					3
2009		1	2	3	1				1	8
2010	1	1	2	1						5
2011	2									2
2012	1					1			1	3
2013										0
2014										0
2015	1				1					2
2016				1						1
2017	2				2			1		5
2018		1			1				1	3
Total	27	17	8	11	10	11	2	1	6	93
Percentage	29%	18%	9%	12%	11%	12%	2%	1%	6%	

It is noticeable that the management category has the most significant number of published articles around the timeline. On the other hand, there is only one article in the environment category. More details about the number of articles in each category are described in the table below.

Table 5: Number of articles per category

Category	Number of studies	Percentage
Management	27	29%
Planning	17	18%
Technical	8	9%
Business	11	12%
Economy	10	11%
Social	11	12%
Policy	2	2%
Environment	1	1%
Mix	6	6%
Total	93	

4.2. Demography

The articles in this study were selected to cover the majority of countries around the world. Categorizing articles based on demography would give a clearer idea about how different countries are interacting with AMT adoption and implementation. Each study was assigned to a country based on the place where the study was conducted. Almost all articles ware categories into countries except one article that didn't used a quantitative methodology or conduct any study but was used as a literature review for other articles. The following table and graph show the demography categorization of the studies.

Table 6 and Graph 2: Number of Studies per Country

Country	Number of articles
USA	39
UK	7
India	9
Malaysia	5
Brazil	2
Spain	2
Canada	2
Pakistan	2
Sweden	1
Singapore	2
Hong Kong	2
Taiwan	2
Australia	2
Saudi Arabia	3
New Zeland	1
China	1
Mexico	1
Czech Rep.	1
Greece	1
Eygpt	1
South Africa	1
South Korea	1
Germany	1
Italy	1
Thailand	2
Russia	1
Hungary	1
Malta	1

From the above representations of the article's demography, it is obvious that the United States has the largest numbers of published articles by 39 articles followed by India which has nine articles. This can be an indication of the critical role of educational and research institutes in the amount and the quality of articles published in these United States. Also, the massive number of companies that are concerned with AMT in the Country. Furthermore, when comparing the number of articles between developed and developing countries, it is clear that developed countries have far more published articles than in developing countries. The percentage of published articles in developed countries is almost 67% while developing countries have 32% of the articles included in this literature review.

5. RESEARCHES GAPS AND FUTURE WORK

The critical gap in most of these articles is represented by the lack of making the necessary integrations between different critical factors that might have an impact on AMT adoption. To deeply understand the drivers and barriers of AMT adoption, it is important to have control over the critical factors from different dimensions. The previously mentioned dimensions such as planning, management, business etc..., can provide a broader view to understand how the adoption process works. Moreover, the integrations and interactions between the critical factors within the different dimensions should be deeply investigated and

studied. However any future work should highlight the interaction between the critical factors from the eight different dimensions. The integrations of the different critical factors can assure a successful adoption of the AMT. In the same time, the future efforts should focus on the new scientific approaches such as Industry 4.0, machine learning and internet of things in order to get benefits of these approaches in the AMT adoption and implementation.

6. CONCLUSION

To conclude, it is possible to say that the adoption process of the AMT is somehow complicated than what firms or governments might think. The sensitive nature of the AMT implementation makes it somehow risky to deal with. For that purpose, it is necessary to determine any critical factors associated with the adoption of the AMT and highly control these factors to come up with successful AMT implementation practices. Highlighting the AMT critical factors from different dimensions would provide decision-makers with a broader view of any issue that might get into the way of successful implementations for the AMT.

Categorizing adoption critical factors into different dimension can also help in following the root cause of any problem that might face the AMT implementation and eliminate them at early stages. Also, considering those critical factors before the adoption can be very helpful in uncovering any uncertainties associated with the implementation process. Moreover, using previous studies to conduct a systematic literature review is considered to be an effective approach to determine the critical factors of AMT adoption. However, conducting a quantitative research methodology such as questionaries would be ideal to discover how these different factors are interacting with each other.

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