Review

Categorizing Critical Factors of Advanced Manufacturing Technology Implementation Globally

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Abstract: This paper presents a systematic literature review that identifies critical factors impacting the implementation of advanced manufacturing technology (AMT) worldwide. The study utilizes two databases, ProQuest and Compendex, as well as Google Scholar. The study identified eight dimensions that illustrate the critical factors of AMT adoption and implementation: education, planning, top management know-how, technical know-how, business, economic impact, regulations, and social impact. The results highlight a research gap in understanding the need for effective integration among these eight dimensions in developed and developing economies. Consequently, the study recommends the adoption of a broader perspective that considers the role of integration and interaction between critical factors in each category and their impact on AMT implementation. The systematic literature review conducted in this study reviews several critical factors related to the adoption and implementation of AMT.

Keywords: Advanced Manufacturing Technology (AMT); Systematic literature review; Implementation; Adoption ; Critical Factors

1. Introduction

Advanced Manufacturing Technology (AMT) refers to the adoption of various hard and soft technologies developed to improve manufacturing capabilities [1]. Different types of AMT are used for specific manufacturing purposes and are functionally classified. The practical applications of AMT contribute to the rapid growth of the global industrial sector. However, the rapidly changing technology presents both opportunities and risks. It is crucial to adopt and implement AMT correctly to add value to the industry, optimize output, and avoid uncertainties [2,3].

The adoption of AMT plays a pivotal role in driving industrial transformation in any country. However, it is challenging due to the complexities associated with the implementation process [4]. The critical factors impacting AMT adoption in one area of the industry can also be applicable to other areas reliant on technology. From a broader perspective, AMT adoption is closely tied to the rapid growth of technology [5], encompassing various types of manufacturing and industry applications.

Currently, substantial investments are directed towards adopting new AMT for different manufacturing purposes to achieve competitive excellence [6]. However, uncertainties associated with AMT adoption and implementation pose challenges to industrial development [7]. Uncovering these uncertainties is crucial for research and development efforts to ensure a healthy and competitive industrial sector. To better understand the potential of AMT implementation, this study conducted a systematic literature review of published studies using the PRISMA approach to categorize the critical factors impacting AMT implementation.

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2. Materials and Methods

This systematic review utilizes the research contained in the ProQuest and Compendex databases, as well as the Google Scholar search engine. The search was conducted using specific keywords, as shown in Table 1, to minimize potential bias and enhance the overall quality of the review. The search encompassed studies published between 1985 and 2022. In the screening process, inclusion criteria were applied to assess the content of the studies, resulting in a final set of 109 studies. The studies were then analyzed to identify their coverage of the eight dimensions of AMT implementation, which include education, planning, top management know-how, technical know-how, business, economic impact, regulations, and social impact.

As a result, a total of 1,282 studies from the ProQuest database, 864 studies from the Compendex database, and 1,822 studies from the Google Scholar search engine were identified. The inclusion criteria for this phase included documents published between 1985 and 2022. In the second phase, additional keywords were added to narrow down the search results, resulting in a total of 679 screened documents. In the third phase, inclusion criteria were applied to assess the content of the studies from the previous phase, resulting in a total of 457 studies. The inclusion criteria included studies written in English, peer-reviewed, book chapters, and official governmental reports.

In the second phase, a detailed assessment of the full text of the studies was conducted to ensure that each study addressed one or more of the specified eight dimensions of AMT implementation, namely education, planning, top management know-how, technical know-how, business, economic impact, regulations, and social impact. At the end of this phase, a total of 109 studies were included, with 41 studies from ProQuest, 33 studies from Compendex, and 35 studies from Google Scholar.

Table 1: Systematic review search, keywords, and results.

Search Phase	ProQuest	Compendex	Google Scholar	Total
All articles contain at least one of the following keywords in their abstract or title: AMT AND Critical factors, AMT AND Challenges, AMT AND Barriers, AMT AND Adoption, and AMT AND Implementation.	1,282	864	1,822	
All articles contain at least one of the additional keywords in their abstract or title: country, economy, company, organization, sector, and industry.	206	127	346	
All articles with substantively relevant text (fit for purpose)	122	104	231	

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All articles with effectively relevant text (fit for purpose)	41	33	35	109

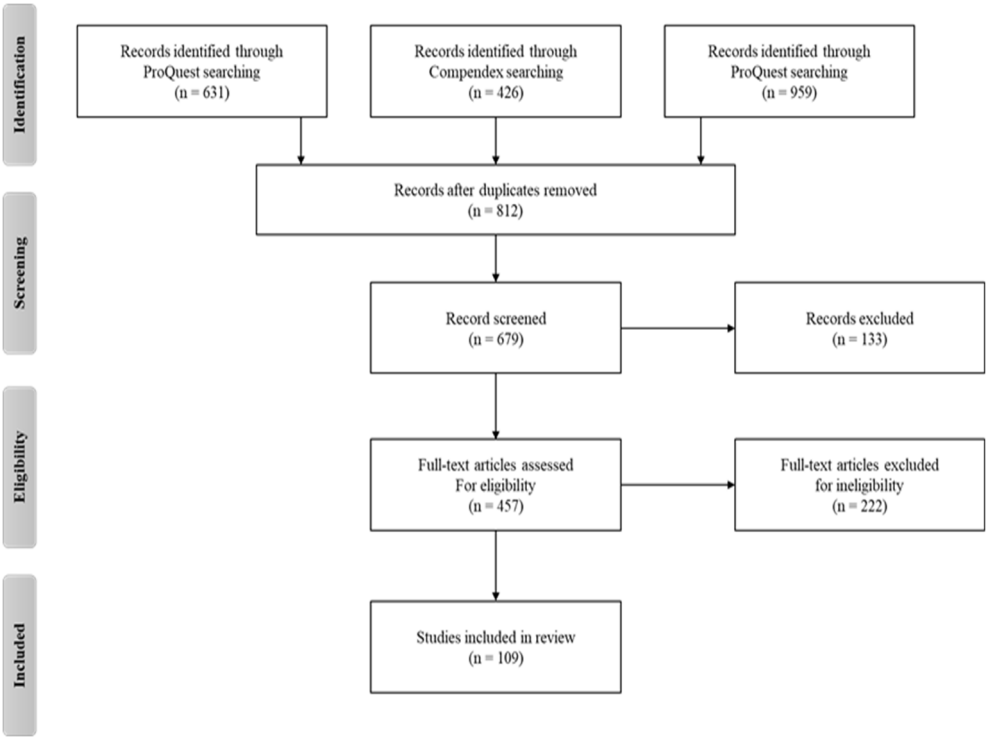

Figure 1: PRISMA flowchart of the review process.

3. Results

This systematic review identified 109 published studies that examined the critical factors of implementing AMT, as shown in Table 2 and Figure 2. These studies were analyzed in relation to the eight dimensions of AMT implementation. A significant number of studies (n = 32; 29%) focused on the top management dimension. The economy dimension had a similar number of studies (n = 13; 12%) as the technology dimension (n = 13; 12%). The education and regulations dimensions each had five studies (5%) associated with them. Additionally, there were 12 studies (11%) categorized under the business dimension, 10 studies (9%) under the social dimension, and 6 studies (6%) under the planning dimension. The remaining studies addressed critical factors that spanned multiple dimensions and were categorized as an additional mixed category, which comprised 13 studies (12%).

Table 2: Number of studies per category.

Category	Number of studies	Percentage
Education	5	5%
Planning	6	6%
Management	32	29%
Technology	13	12%
Business	12	11%
Economy	13	12%
Regulations	5	5%
Social	10	9%
Mix	13	12%
Total	109	

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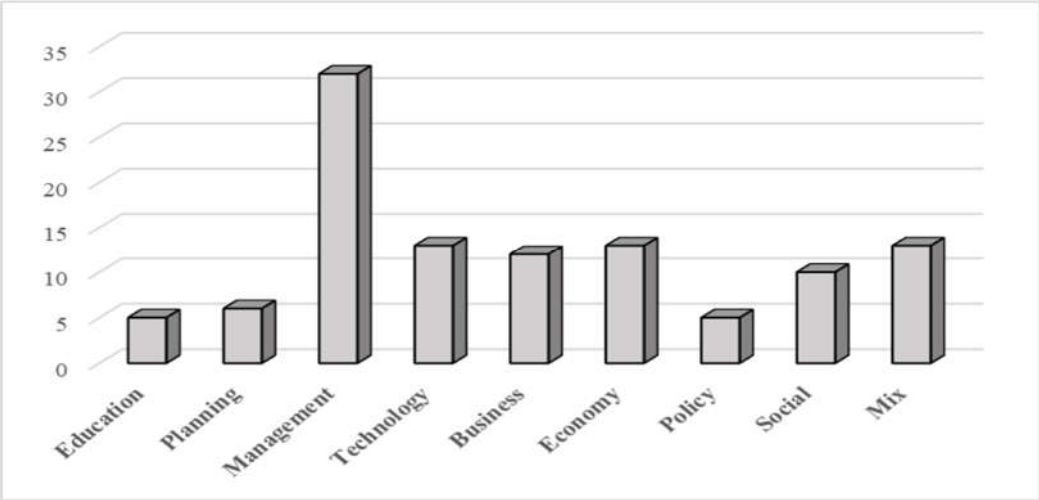

Figure 2. Distribution of studies among categories.

The studies included in this literature review covered a wide range of countries globally. Categorizing the studies based on demography involved assigning each study to a country based on the location where the research was conducted, as shown in Table 3. The studies covered a total of twenty-eight countries. The United States had the largest number of published articles, with thirty-four studies representing thirty-one of the studies included in this literature review. The significant number of studies conducted in the US highlights the crucial role of educational and research institutes in generating high-quality research on AMT, as well as the substantial number of companies involved in AMT applications in the country. Furthermore, a comparison between the number of studies conducted in developed and developing countries reveals that developed countries have a much higher number of published studies than developing countries. Developed countries accounted for sixty-seven percent of the published articles, while developing countries represented thirty-two percent of the studies included in this literature review.

Table 3. Number of studies per Country

Country	Number of studies
Australia	3
Brazil	3
Canada	3
China	3
Cyprus	2
Czech Republic	1
Egypt	1
Germany	1
Hong Kong	2
Hungary	1
India	11
Iran	2
Italy	1
Kenya	1
Malaysia	7
Malta	1
Mexico	1
New Zealand	1
Pakistan	2
Russia	1
Saudi Arabia	3
Singapore	3
South Africa	1

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South Korea	1
Spain	3
Sweden	3
Taiwan	3
Thailand	3
UK	8
USA	34

This systematic literature review analyzed a total of one hundred and nine studies that were published from 1985 to 2022 and are non-uniformly distributed in time (Figure 3). Except for a few notable spikes in the number of studies published in 1992 and 2009, there is no obvious pattern or trend in the information available. The fact that the number of studies published increased between 1992 and 2009 may indicate that there were significant developments or breakthroughs in advanced manufacturing technology during those years, which caused an increase in interest and activity in the field. Furthermore, the number of published studies at a specific time might vary according to different circumstances, such as the dominant manufacturing technology of each period.

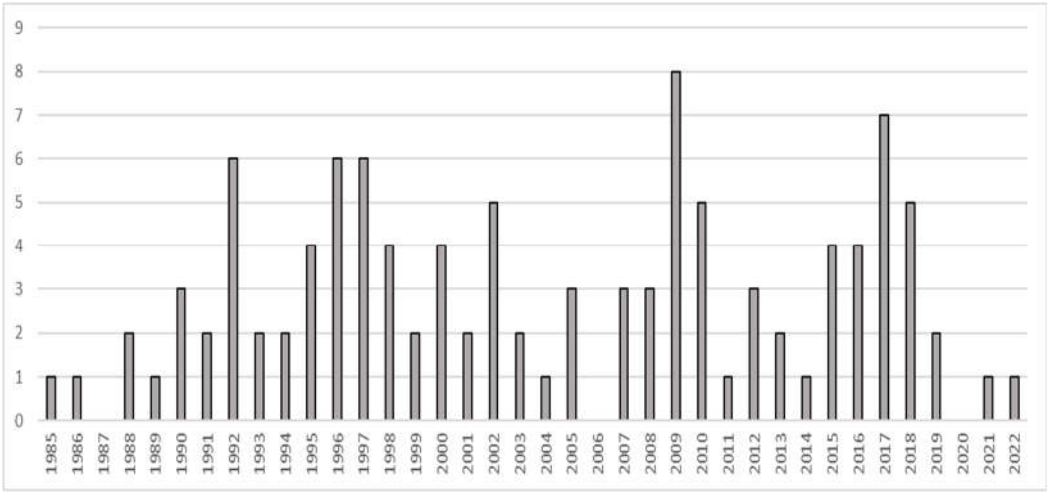

Figure 3. Temporal distribution of studies.

4. Discussion

The main focus of this study was to categorize the critical factors that impact AMT implementation based on specific dimensions: education, planning, top management know-how, technical know-how, business, economic impact, regulations, and social impact. Below, we discuss each category in relation to AMT adoption and implementation, as represented in Figure 4.

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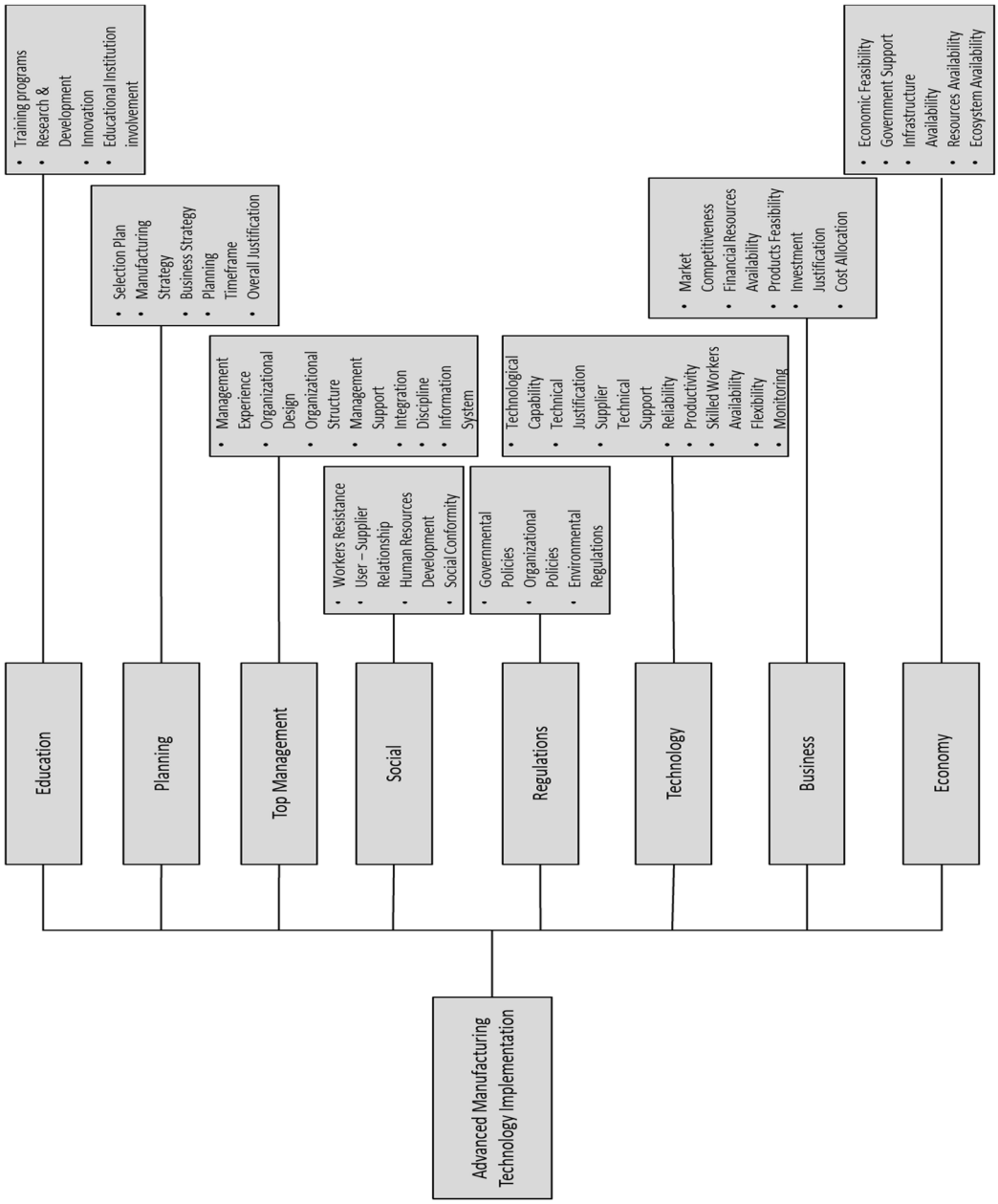

Figure 4. Classification of critical factors in included papers.

Education and training play a crucial role in advancing the manufacturing process, particularly in complex sectors that require the establishment of global education and training centers [8]. Access to appropriate training and education enables any economy to compete in the industrial field effectively. Education is essential not only for familiarizing workers with industrial technology but also for overall development [9]. Training also helps overcome barriers between workers and technology, leading to maximum productivity [10]. Moreover, education lays the foundation for the fundamental skills and knowledge required to operate AMT [11]. Additionally, research and development are vital for the effective implementation and adoption of AMT. Continuous innovation in technology through research and development ensures the ongoing improvement of AMT's effectiveness. Table 4 presents the critical factors of AMT implementation from an educational perspective.

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Table 4. Critical factors of the education dimension.

Critical Factor	References
Training programs	[12], [13], [14], [8], [9], [11], [15], [10], [16], [17], [18], [6], [19], [20], [21], [22]
Research and development	[12], [14], [23], [24], [25], [17], [26], [18], [27], [28], [29], [30], [31], [32], [33]
Innovation	[34], [35], [3], [36], [37], [38], [39], [40], [41], [42]
Educational institutions involvement	[10], [33]

Successful implementation of advanced manufacturing technology requires careful planning. Developing workable and reliable plans, as well as focusing on specific areas of AMT execution to maintain competitive advantages, represent the most challenging phase of the planning process [4]. In addition to having a suitable operational strategy, selecting an AMT that aligns with short- and long-term operational goals is crucial [43]. Proper planning is necessary to choose and implement the appropriate AMT, considering its integration with other essential elements such as operational, manufacturing, and business strategies. Selecting the right manufacturing technology is essential to ensure that businesses benefit from the continually evolving technological landscape [11]. The manufacturing strategy plays a significant role in selecting the appropriate AMT at the right time and continuously updating the plan to incorporate new technologies [44]. Additionally, the success or failure of AMT implementation efforts heavily relies on the business strategy [45]. Therefore, the planning timeline is a crucial consideration during the AMT selection process and can indicate the success of the procedure [46]. Table 5 showcases the critical factors of AMT implementation from a planning perspective.

Table 5. Critical factors of the planning dimension.

Critical Factor	References
Selection Plan	[47], [4], [35], [43], ([2]), [23], [48], [16], [49], [2], [44], [50], [26], [51], [6], [52], [46]
Manufacturing Strategy	[43], [36], [9], [11], [44], [51], [53], [54], [55], [56], [43], ([2]), [9], [57]
Business Strategy	[2], [23], [58], [59], [50], [51], [60], [49], [45], [23], [55], [61], [40]
Planning Timeframe	[4], [46], [12], [47], [23], [62]
Overall Justification	[12], [2], [58], [63], [4], [44]

The adoption of advanced industrial technology is highly dependent on effective management approaches [64]. Thus, top management plays a pivotal role in the adoption and implementation of AMT, as it ensures the internal alignment necessary to achieve this goal. Implementing AMT can be risky if management lacks fundamental knowledge of manufacturing technology [64]. Organizational design is equally crucial to the success of AMT adoption, as it provides the necessary flexibility to accommodate new technologies [36]. Implementing new AMT requires a transaction process that carries risks for the organization, necessitating an adequate organizational structure to manage any changes [47]. It is the responsibility of top management to maintain a positive organizational culture during the changes resulting from AMT implementation [9]. Management support and commitment are crucial when adopting AMT [65]. Integrating various managerial aspects is necessary to ensure successful AMT adoption and implementation [12]. Likewise, the management's dedication and discipline will inspire workers throughout the organization to complete tasks correctly each time they interact with AMT [66]. Table 6 shows critical factors of AMT implementation from a management perspective.

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Table 6. Critical factors of the management dimension.

Critical Factor	References
Organizational Design	[47], [36], [11], [24], [67], [63], [68]
Organizational Structure	[12], [13], [47], [69], [64], [11], [16], [44], [70], [22], [22], [31]
Organizational Culture	[13], [58], [9], [25], [71], [71], [17], [20], [68]
Management Support	[85], ([3]), ([2]), [69], [64], [9], [72], [24], [71], [16] [17], [59], [50], [73], [52], [19], [55], [28], [61], [67], [56], [74], [75]
Integration	[12], [59], [66], [76]
Information System	[77], [9], [38], [29], [30], [78]

Improved performance is often driven by a strong technological capacity, which motivates organizations to continually enhance their technical skills. During the AMT selection phase, it is crucial to assess the organization's workforce capabilities and their ability to manage modern technology effectively [12]. Therefore, the technical strategy must address all technical aspects of implementation while identifying the necessary technological prerequisites for AMT approval [67]. Additionally, conducting a technical justification is crucial in evaluating the advantages and disadvantages of AMT during the selection process [79]. Collaboration between the AMT supplier and user at the early stages of implementation can also play a crucial role [56]. Furthermore, creating a knowledge base that outlines the required technical qualifications and abilities of workers operating the implemented AMT is essential [11]. Reliability, productivity, flexibility, and monitoring are further critical technical attributes for successful AMT implementation. Table 7 presents the critical factors of AMT implementation from a technical perspective.

Table 7. Critical factors of the technical dimension.

Critical Factor	References
Technological Capability	[12], [35], ([3]), [23], [9], [50], [67], [1]
Technical Justification	[43], [2], [24], [25], [59], [49], [80], [62], [22], [63], [79], [81]
Supplier Technical Support	[12], [15], [82], [45], [73], [67], [56], [83], [84]
Reliability	[85], ([3]), ([2]), [69], [64], [9], [72], [24], [71], [16] [17], [59], [50], [73], [52], [19], [55], [28], [61], [67], [56], [74], [75]
Productivity	[13], [58], [72], [59], [51], [37], [86], [63], [87], [88]
Flexibility	[89], [14], ([2]), [72], [71], [59], [26], [18], [90], [23], [86], [76], [22]
Monitoring	[43], ([2]), [69], [23], [25], [98], [26], [60], [90], [70], [38], [62], [91], [29], [74], [92], [93]

The implementation of AMT is a crucial element that helps manufacturing organizations worldwide in reducing manufacturing costs, improving output quality, and enhancing desired results and production flexibility. When implementing new manufacturing technology, organizations are primarily driven by the potential financial gains, which has led to the widespread adoption and growth of AMT in recent decades, contributing to the stability and expansion of the technology itself [51]. However, organizations also face the challenge of producing more with fewer resources while improving their products and bringing them to market faster than competitors through AMT implementation [87]. From a business perspective, the availability of financial resources directly influences AMT implementation [67]. Additionally, product feasibility and investment justification are critical factors in the decision-making process for AMT adoption and implementation. Similarly, cost allocation is a major objective pursued by industrial organizations through AMT implementation, as it aligns with resource allocation [82]. Table 8 illustrates the critical factors of AMT implementation from a business perspective.

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Table 8. Critical factors of the business dimension.

Critical Factor	References
Market Competitiveness	[58], [9], [48], [71], [59] [26], [60], [37], [49], [90], [27], [55], [94], [87], [32], [95], [96], [97]
Financial Resources Availability	[12], [48], [16], [38], [67], [56]
Products Feasibility	[4], ([3]), [48], [44], [82], [49], [39], [62], [95], [96]
Investment Justification	[85], [69], [5], [58], [44], [98], [6], [55], [39], [67], [99], [63], [96], [100]
Cost Allocation	[12], [13], ([3]), [77], [58], [82], [53], [96]

Advanced industry plays a vital role in driving significant economic growth for nations. When it comes to adopting and implementing AMT processes, the economic situation can act as either a driver or a barrier [25]. Therefore, the implementation of AMT should be oriented towards maximizing economic benefits through proper economic justification [79]. However, realizing the economic advantages of AMT adoption and implementation requires government support [5]. The collaboration between the government and the private sector contributes to the development of thriving economic and industrial infrastructure, which is advantageous for AMT adoption in these countries [39]. Additionally, the availability of an ecosystem and resources is critical for enabling both local and international competitive advantages of AMT. Table 9 illustrates the critical factors of AMT implementation from a technical perspective.

Table 9. Critical factors of the economic dimension.

Critical Factor	References
Economic Feasibility	[25], [80], [63], [32], [79], [101]
Government Support	[12], [102], [5], [10], [32], [101]
Infrastructure Availability	[12], [43], [85], [14], [5], [15], [53], [54], [39], [91], [22], [46]
Resources Availability	[85], [102], [5], [17], [60], [88]
Ecosystem Availability	[50], [103], [60], [80], [39], [67], [104]

The effectiveness of any technological advancement is primarily evaluated through human-technology interaction. It is crucial to consider social impact as it can either hinder or facilitate industrial changes related to manufacturing technologies [76]. In terms of social impact, worker resistance is a critical factor influencing AMT implementation [4]. Workers tend to resist any modifications that reduce the reliance on human labor in the industrial process [105]. On the other hand, the user-supplier relationship plays a key role in the successful implementation of AMT [69]. To avoid conflicts between technological and human components of the manufacturing process, human resources development must align with the adopted AMT [56]. Furthermore, worker behavior towards these manufacturing technologies influences social conformity [92]. Table 10 outlines the critical factors of AMT implementation from a social perspective.

Table 10. Critical factors of the social dimension.

Critical Factor	References
Workers Resistance	[12], [13], [4], [43], [14], ([3]), [9], [72], [17], [44], [66], [45], [55], [76], [105]
User–Supplier Relationship	[85], [69], [9], [15], [26], [106], [45], [73], [61], [67], [46], [83], [84], [7]
Human Resources Development	[43], [11], [72], [15], [25], [17], [59], [98], [18], [107], [61], [22], [67], [56]
Social Conformity	([3]), [102], [71], [59], [76], [105], [92]

 doi:10.20944/preprints202306.0786.v1

To maintain a healthy industrial environment, a set of rules and regulations must govern industrial activities and provide necessary adjustments. Governments and their agencies are responsible for creating and revising these laws and regulations. The success of AMT adoption is influenced by regulations that foster an environment conducive to achieving the goals of manufacturing technology [7]. Therefore, governments have the responsibility of establishing a solid foundation of laws and rules that encourage the adoption and implementation of AMT. Government agencies play a crucial role in establishing regulations and laws related to AMT implementation [15]. It is essential for government and organizational regulations to align with each other. Additionally, environmental regulations have become a global concern and influence the adoption and implementation of AMT (González-Torre, Alvarez et al. 2010). Table 11 presents the critical factors of AMT implementation from a regulatory perspective.

Table 11. Critical factors of the regulation dimension.

Critical Factor	References
Governmental Policies	[23], [59], [54], [7], [108]
Organizational Policies	[23], [15], [26], [54], [56], [7]
Environmental Regulations	[77], [109], [5], [110]

As for the limitations of this systematic review, we acknowledge that not all studies relevant to our evaluation may have been included in this review. Despite using closely relevant keywords during the scanning phase, the limited number of keywords used might have hindered the identification of specific appropriate papers. Furthermore, the language restriction may have resulted in the omission of relevant studies published in other languages. Additionally, certain relevant studies may have been overlooked during the screening stage due to the databases not indexing every relevant study or the search terms being too specific. Moreover, inconsistencies in the applied inclusion criteria could limit the conclusions drawn from the review of studies. Finally, the availability of specific bibliographic databases might restrict the scope of finding records.

5. Conclusions

The adoption and implementation of AMT are complex endeavors, regardless of the beliefs of organizations and governments. Implementing AMT carries inherent risks due to its sensitive nature. It is crucial to identify and regulate the critical factors associated with its implementation to ensure successful deployment. Therefore, highlighting the critical factors of AMT from different dimensions is essential to provide decision-makers with a comprehensive understanding of potential issues that may hinder successful implementation. Categorizing critical implementation factors into different dimensions can help identify the root causes of obstacles and address them at the early stages. Furthermore, considering these critical factors before implementation can help reveal and address implementation-related challenges. Therefore, conducting an in-depth review of prior studies on AMT implementation is an effective way to assess the impact of critical factors. Additionally, we recommend that researchers adopt a broader perspective that encompasses the integration and interaction between critical factors in each category and their impact on AMT implementation.

Author Contributions: AAF conducted the literature search and prepared the initial draft of the paper. WK conceived the study conception and supervised all aspects of manuscript preparations, revisions, editing, and final intellectual content.

Funding: This research received no external funding

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 doi:10.20944/preprints202306.0786.v1

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