Chapter 56
Analysis Factors in the Adoption of Digital Manufacturing Technologies in SMEs

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Abstract Small and medium enterprises (SMEs) are investing in adoption of digital manufacturing technologies to scope system complexity, increase information visibility, improve production performance, and gain competitive advantages in the global market. This article presents an analysis of the technology adoption models for the implementation of digital manufacturing to identify which factors influence the implementation process. We discuss the methodology for using technology adoption models. We hope this work will help multidisciplinary research efforts to advance in the adoption of digital manufacturing technologies in SMEs.

56.1 Introduction

Technology adoption refers to incorporating technologies from outside a given system; it is a process of permanent change that unfolds under conditions of uncertainty and diversity of agents. This process is complex from a technical and social perspective because it involves contextual, emotional, and cognitive factors [1]. Thus, when a study focused on implementing one or more digital tools, it is generally done using some available technology adoption model or its adaptation. Each adoption model represents a framework to determine the critical factors influencing the adoption of technologies from users and the technologies' use and behavior within the organization [1].

Digital manufacturing technologies (DMT) belong to the Fourth Industrial Revolution Framework. These key technologies are based on the principles of connectivity, automation, integration, computing, and transforming traditional

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factories into smart ones [2]. Nowadays, companies need to apply adoption models for embracing these technologies to remain competitive and active in the market. Thus, the implementation of DMT is a timely topic that requires attention.

This article uses technological adoption models available in the literature as analytical tools to understand the implementation process of DMT. The analysis is performed to determine how the technological adoption models can be used to adopt DMT, specifically in small and medium enterprises (SMEs). Furthermore, the analysis aims to establish the methodological steps and tools used to evaluate the relationship of the involved factors in adopting the technologies.

The remainder of the paper starts with identification of theoretical and conceptual elements of technology adoption models oriented to the adoption of DMT. Subsequently, a description of the methodology in the implementation of these models is presented. Finally, the article proposes reflections and conclusions about the study of the adoption of DMT in SMEs guided by the theoretical technology adoption models.

56.2 Methodology

Different stages have been proposed to analyze the technology adoption models reported in the literature regarding their application in the adoption of DMT:

(i) A documentary search aimed at collecting information regarding studies related to the use of technology adoption models applied to the implementation process of DMT in SMEs, i.e., integrated engineering systems, digital automation with sensors, simulations, big data collection and analysis, digital product–service items, additive manufacturing, cloud services, and blockchain [3]. The construct used in the research engine was "smart manufacturing" OR "industry 4.0" AND "technology adoption models" AND "SMEs".

(ii) Information filtering by adjusting each database to the specific requirements, such as year of publication (between 2010 and 2021); type of publication (journal articles, conferences, and books); search by title, keyword, and abstract. The filtering allows obtaining highly relevant articles in broad access digital libraries such as Science Direct, IEEE, Taylor and Francis, and Google Scholar.

(iii) The inclusion criteria include studies involving models of adoption of DMT and written in English. As exclusion criteria, non-relevant studies have been disregarded, namely studies that do not discuss the use of digital manufacturing technology adoption models.

(iv) Identify the constructs employed within the proposed model. Then group constructs with similar characteristics and find out those constructs oriented to DMT technical characteristics and SME's particular.

Initially, a total of 89 studies were obtained. An analysis of each of the selected studies was performed to determine the adoption model involved, the scope of application, and the results obtained. Then, by comparing the selected studies, it was possible to determine common stages, establish the tools used, and group them according to similar characteristics. Finally, the results of each study were considered to obtain the common factors involved in the process of implementation of DMT in SMEs.

Some general conclusions are presented in the following section regarding the scope of the models of adoption of DMT in SMEs.

56.3 Results and Discussion

Technology adoption is a complex process from a technical and social perspective that also involves contextual, emotional, and cognitive factors [1]. For this reason, when a study involving the implementation of a digital tool or several tools is conducted, it is generally done using some adoption model present in the literature or an adaptation of it. Technology adoption models have been applied in various fields to understand and determine which critical factors influence this process [4].

According to the selected studies, it must be highlighted that the implementation of a technology adoption model begins with selecting the model that fits the needs to be explored. Moreover, each model presents some constructs or main factors related to each other, and each construct could consist of more specific factors.

Regarding models and theories of technology adoption, the literature presents the following: Diffusion of Innovations Theory (DOI), Technology Organization Environment (TOE), Technology Acceptance Model (TAM), Theory of Planned Behavior (TPB), Theory of Reasoned Action (TRA), Theory of Interpersonal Behavior (TIB), Unified Theory of Acceptance and Use of Technology (UTAUT), among others [1].

Within the implementation process of DMT, technology adoption models allow identifying relationships between the technological tool and the process in which it is implemented. For example, authors in [5] identify blockchain's relationship with supply chain management, taking as an analysis tool an adaptation of the TOE model. Similarly, in [6], blockchain analysis in supply management systems is performed using an adaptation of the TOE and TPB models. Furthermore, in [7], an adaptation of TAM and ECM is presented to study the implementation of digital manufacturing.

The models of adoption of DMT can be used not only within industrial processes as discussed in [5–7] but also in non-industrial processes, as evidenced in [8], where a study is conducted through the theory of planned behavior (DTPB) model to analyze big data in disaster management.

The adoption models used in the analyzed studies are compiled in Table 56.1, differentiating those oriented toward SMEs.

Table 56.1 Adoption models used

ID	Author	SMS's	Model
1	Masood and Sonntag [9]	YES	TAM
2	Junior et al. [10]	YES	TOE—DOI
3	Khayer et al. [11]	YES	TOE
4	Mayaram et al. [12]	YES	TOE
5	Khayer et al. [13]	YES	UTAUT—TOE
6	Rababah et al. [14]	YES	TOE
7	Ghobakhloo and Ching [15]	YES	TOE
8	Awa and Ojiabo [16]	YES	TOE
9	Masood and Egger [17]	NO	TOE
10	Fosso Wamba et al. [5]	NO	TOE
11	Zaman et al. [8]	NO	DTPB
12	Kamble et al. [6]	NO	TAM—TPB
13	Sepasgozar [7]	NO	TAM—ECM

According to the analysis of the selected studies, the most widely applied model is the TOE and its implementation together with other adapted models. TOE is a classical framework that proposes a generic set of factors that influence the adoption and/or implementation of technological innovations: the organizational context, the environmental context, and the technological context [4].

The adoption models reported in the literature present some general constructs already established, on which specific characteristics of analysis are defined. Specifically, the general constructs of the adoption models mentioned in the studies analyzing SMEs are described as follows. In [9], the TAM model was used with the following general constructs: external factors, perceived challenges, and perceived benefits. Studies [10–12, 14–16] used the TOE model, with the following general constructs: organization context, technology context, and environment context. In [13], an adaptation of the TOE and UTAUT models is made, and the following constructs were defined: performance expectancy, effort expectancy, absorptive capacity, technology readiness, competitive pressure, regulatory support, data security and privacy, and perceived trust.

After selecting a model and defining the characteristics in each construct, possible relationships between them, known as hypotheses, are established. For example, in [9], the model used was the TOE. Within the general constructs (explained previously), the following specific characteristics were defined for the external factors construct: Company size, manufacturing complexity, and attitude toward Industry 4.0. Next, six hypotheses were defined, seeking to relate the constructs to each other, as shown in Fig. 56.1.

Once the theoretical model has been adapted to the particular problem, the validation process begins. Most studies use questionnaires or surveys as data collection tools to validate the hypotheses formulated. Usually, the Likert scale is used as a measurement tool in this type of questionnaire since the factors analyzed are

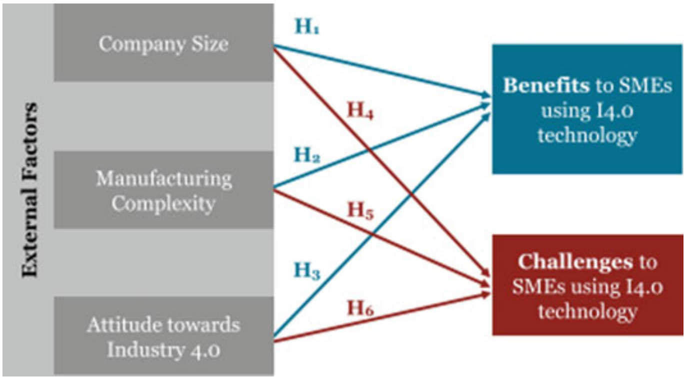

Fig. 56.1 Example of a proposed technology adaption model. Taken from [9]

generally qualitative. Moreover, with this scale, the answers can be offered at different levels of measurement from a quantitative point of view [18].

Initially, the data collected from the questionnaires were processed using statistical tools for reliability and data quality analysis. Next, the relationship modeling of the constructs evaluated was performed, i.e., the design of a formalism to evaluate the proposed hypotheses from the data based on construct relationship tools [19].

It can be seen that in the studies analyzed, a combination of these tools is used to validate data reliability. Table 56.2 contains a compilation of the statistical tools applied.

Table 56.2 Compilation of statistical tools

Reliability tools
Kaiser Meyer Olkin (KMO)
Mardia multivariable test of normality
Robust maximum likelihood MLM
Satorra–Bentler corrected
Cronbach's Alpha
Dijkstra–Henseler's rho
Average variance extracted (AVE
Heterotrait-monotrait ratio of correlations (HTMT)
Fornell-Lacker criterion
Maximum Likelihood (ML) method
Importance–performance map analysis (IPMA)
Variance inflation factor (VIF)
Kaiser Normalization
The Exploratory Factor Analysis
Common Method Variance (CMV)

The tools used in the studies analyzed for construct relationship analysis are structural equation modeling (SEM), partial least square method (PLS-SEM), neural network analysis, technology adoption decision-making, and multiple regression analysis. Notice that from the total of the selected studies (13 studies), there is a preference for the SEM tool and its variant partial least square method (PLS-SEM) since nine of them apply it.

SEM is a set of multivariate statistical techniques, which establish the dependence relationship between variables. Within SEM, there are two types of approaches: covariance (CB-SEM) and the PLS-SEM, establishing the dependency relationship between the variables involved. When working with SEM, there is the advantage of testing all the hypotheses simultaneously since each variable's behavior is analyzed against the others [19].

Data interpretation through these tools helps establish whether the model is correct and the acceptance or rejection of the proposed hypotheses.

56.3.1 Methodological Application of Models in the Adoption of Digital Manufacturing Technologies in SMEs

Some studies in the literature identified the use of technology adoption models for adopting DMT in SMEs, taking into account some particular characteristics of SMEs, such as size, purchasing power, and the type of industry [12].

Authors in [9] use the TOE model to analyze the benefits and challenges of implementing DMT in SMEs. In [15], an analysis of the influence factors of technologies on DMT implementation in SMEs is presented. Similarly, in [10], the TOE model is used to adapt a tool of the technological pillars defined for Industry 4.0 as a vertically integrated enterprise resource planning (ERP) system applied to SMEs. In [11], a study of the implementation of cloud computing in SMEs is performed using SME and neural network analysis. Another tool analyzed with an adaptation of TOE is presented in [12], where the ERP integration tool in SMEs is examined. In [13], the TOE plus UTAUT model is adapted to evaluate the implementation of cloud computing technology in SMEs. Similarly, in [14], TOE is used to analyze cloud computing implementation in SMEs in Jordan.

From DMT are identified augmented reality, blockchain, and big data analyzed in the selected studies. And cloud computing and ERP analyzed in the selected studies about SMEs.

The impact of DTM adoption is highlighted in [7] since it improves the understanding of the digital technologies providers and improves the behavior of the customers toward their use, which increases the adoption rate. Authors in [5] indicate that knowledge sharing among stakeholders and pressure from partners in adopting blockchain technology are good predictors for technology implementation. Moreover, they also state that the type of manufacturing company does not represent a determining characteristic for the implementation. In [17], the authors conclude that technological factors and organizational fit are critical for augmented reality adoption success. In [6], evidence is provided toward stating that the perceived usefulness, attitude, perceived behavioral control, and subjective norms are directly related to applying the blockchain technology tool. Notice that the studies mentioned above are applied to industry in general.

On the other hand, the finding for studies focused on the application and/or adoption of DMT, particularly in SMEs, is presented as follows. According to [9], most SMEs struggle with the abundance of available digital technologies, the time to learn about them, and the funding to implement them. Furthermore, the size and type of the company affect the benefits of implementing DMT. Similarly, [16] identifies that firm size is a determinant of ERP adoption, in addition to infrastructure, technical know-how, perceived compatibility, perceived values, and security. Thus, [16] highlights that ERP adoption is mainly driven by technological factors.

In [13], it follows that SMEs should focus their attention on developing technology infrastructure and ICT knowledge to get the maximum benefit from cloud computing adoption. Similarly, [14] proposes that technology availability and compatibility have the most significant influence on cloud computing adoption. In [15], the authors recognize that planning each step is necessary for SMEs, e.g., having a timeline and detailed costs and benefits associated with the adoption of DMT. The authors also state that the strategic path should address technology maturity, digitization maturity, organizational readiness, digitization knowledge, and integration capability. Hence, maturity models are proposed as an assessment tool.

Other studies, on the contrary, mention that the firm size variable is not important in the explanation of ERP adoption [10]. Authors in [11] also identify that firm size and type do not cause significant variation in the performance of cloud computing adoption.

It should be remarked that there are common analysis factors, such as technology compatibility, technological knowledge, company size, and implementation costs. However, although they are notable and relevant to be studied, these are not necessarily positively influencing variables.

56.4 Conclusion and Further Studies

From the information gathered, it can be inferred that it is necessary to examine the technical components of implementation as well as the social and administrative components involved to analyze the adoption of technologies within a system.

For this reason, the technology adoption analysis process is guided by theoretical technology adoption models. These models provide theoretical bases for the various components present in technology adoption. An analysis methodology is distinguished, beginning with selecting the theoretical adoption model, particularly adapted to each case's needs. Then, the proposed model needs to be validated through statistical analysis of data collected through questionnaires. Finally, the components that are related to the implementation of the technology can be identified.

It was found that the theoretical technology adoption models have been used to project how the components involved in the implementation can respond to the original system's adoption of a particular technology. It was also shown that the technology adoption models are applied for analyzing the adoption of any technology into any enterprise or process, whether the process is industrial or not. This includes DMT and SMEs, taking into account the company size and the implementation costs.

As a result, in the analysis of the adoption of DMT in SMEs, the following components stand out as common: technological (e.g., technology compatibility, perceived compatibility, and technological readiness); social (e.g., attitudinal, perceived behavioral); and organizational (e.g., management support).

According to the results of analyzing the adoption models of DMT in SMEs, the authors proposed to examine their inclusion in a decision-making model to implement the studied technologies.

References

1. Taherdoost, H.: A review of technology acceptance and adoption models and theories. Proc. Manuf. **22**, 960–967 (2018)
2. Gillani, F., Chatha, K.A., Sadiq Jajja, M.S., Farooq, S.: Implementation of digital manufacturing technologies: antecedents and consequences. Int. J. Prod. Econ. **229**, 107748 (2020)
3. Dalenogare, L.S., Benitez, G.B., Ayala, N.F., Frank, A.G.: The expected contribution of Industry 4.0 technologies for industrial performance. Int. J. Prod. Econ. **204**, 383–394 (2018)
4. Lai, P.: The literature review of technology adoption models and theories for the novelty technology. J. Inf. Syst. Technol. Manag. **14**(1), 21–38 (2017)
5. Fosso Wamba, S., Queiroz, M.M., Trinchera, L.: Dynamics between blockchain adoption determinants and supply chain performance: an empirical investigation. Int. J. Prod. Econ. **229**, 107791 (2020)
6. Kamble, S., Gunasekaran, A., Arha, H.: Understanding the blockchain technology adoption in supply chains-Indian context. Int. J. Prod. Res. **57**(7), 2009–2033 (2019)
7. Sepasgozar, S.M.E.: Digital technology utilization decisions for facilitating the implementation of industry 4.0 technologies. Constr. Innov. (2020)
8. Zaman, U., Zahid, H., Habibullah, M.S., Din, B.H.: Adoption of big data analytics (BDA) technologies in disaster management: a decomposed theory of planned behavior (DTPB) approach. Cogent Bus. Manag. **8**(1), 1880253 (2021)
9. Masood, T., Sonntag, P.: Industry 4.0: adoption challenges and benefits for SMEs. Comput. Ind. **121**, 103261 (2020)
10. Junior, C.H., Oliveira, T., Yanaze, M.: The adoption stages (evaluation, adoption, and routinisation) of ERP systems with business analytics functionality in the context of farms. Comput. Electron. Agric. **156**, 334–348 (2019)

11. Khayer, A., Talukder, M.S., Bao, Y., Hossain, M.N.:Cloud computing adoption and its impact on SMEs' performance for cloud supported operations: a dual-stage analytical approach. Technol. Soc. **60**, 101225 (2020)
12. Mayaram, U., Dussoye, A., Cadersaib, Z.: ERP acceptance model for SMEs based on CSFs. In: Proceedings of NextComp 2019, pp. 1–6 (2019)
13. Khayer, A., Jahan, N., Hossain, M.N., Hossain, M.Y.: The adoption of cloud computing in small and medium enterprises: a developing country perspective. VINE J. Inf. Knowl. Manag. Syst. (2020)
14. Rababah, K.A., Al-nassar, B.A., Al-Nsour, S.N.: Factors influencing the adoption of cloud computing in small and medium enterprises in Jordan. Int. J. Cloud Appl. Comput. **10**(3), 96–110 (2020)
15. Ghobakhloo, M., Ching, N.T.: Adoption of digital technologies of smart manufacturing in SMEs. J. Ind. Inf. Integr. **16**, 100107 (2019)
16. Awa, H.O., Ojiabo, O.U.: A model of adoption determinants of ERP within TOE framework. Inf. Technol. People **29**(4), 901–930 (2016)
17. Masood, T., Egger, J.: Augmented reality in support of Industry 4.0—implementation challenges and success factors. Robot. Comput. Integr. Manuf. **58**, 181–195 (2019)
18. Chintalapati, N., Daruri, V.S.K.: Examining the use of YouTube as a learning resource in higher education: scale development and validation of TAM model. Telemat. Inf. **34**(6), 853–860 (2017)
19. Davvetas, V., Diamantopoulos, A., Zaefarian, G., Sichtmann, C.: Ten basic questions about structural equations modeling you should know the answers to—but perhaps you don't. Ind. Mark. Manag. **90**, 252–263 (2020)