



# Applying Industry 4.0 technologies for the sustainability of small service enterprises

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## Abstract

Despite the potential of Industry 4.0 (I4.0) to make micro, small and medium enterprises (MSMEs) sustainable, the managers of service MSMEs find it tough to implement it in their firms. Drawing on the TAM and TAM2, this paper identifies I4.0 technologies (I4T) that help improve the sustainability in service MSMEs in the emerging economy of India. Data from different service MSMEs were collected to assess the importance of I4T. Artificial Intelligence, Big Data Analytics, and Internet of Things emerge as the most important I4T for sustainability. Several managerial implications along with theoretical contributions, limitations, and future research have been discussed.

**Keywords** Industry 4.0 · Sustainability · Service MSMEs

## 1 Introduction

The service sector is one of the most essential segments for the development of emerging economies, as many emerging nations generate a major portion of their revenue by outsourcing their services globally (Ostrom et al. 2010). Service is defined as "... an intangible act or use for which a consumer, firm, or government is willing to pay" (McConnell et al. 2009, p. G-25). Services such as banking, healthcare, tourism, hospitality, entertainment, technology, and education form the most fundamental services of an economy for the peoples' security, well-being, and prosperity. The COVID-19 pandemic being the new normal, conducting studies on how this new normal will impact digitalization in the service industry is imperative (Rha and Lee 2022). Post the pandemic, companies have begun to look for viable

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service providers in emerging countries to establish the upstream of their service supply chains in these nations to mitigate their supply chain risk. For instance, the Indian service sector has received a cumulative foreign direct investment (FDI) of US\$ 94.19 billion between April 2000 and March 2022, ranking the sector first in FDI inflow (IBEF 2022). Large firms and multi-national companies in the service sector are aware of this global shift towards investment in digital technology and are preparing to encash this opportunity. However, the micro, small and medium enterprises (MSMEs), i.e. enterprises whose investment in plant, machinery or equipment is not more than ₹50 crores ( $\approx$  US\$ 6.26 million, see Table A1 of Appendix for more details on classification and conversion rate), and annual turnover is not more than ₹250 crores ( $\approx$  US\$ 31.28 million), in the service sector of emerging nations have little to no awareness of this shift, and the opportunities and challenges that come with it. Thus, to stay globally competitive, service MSMEs must be at par with the global trends in the service sector.

Sustainability is one of the most important factors that can help the service MSMEs become and stay globally competitive (Cantele and Zardini 2018). As described by the Harvard Business School in a blogpost of the Business Insights Blog, sustainability means "... doing business without negatively impacting the environment, community, or society as a whole." (Spiliakos 2018). Studies such as Nouri et al. (2019) have shown that service firms can achieve sustainability by properly implementing the digital technologies for information and knowledge management. Industry 4.0 (I4.0), also known as the fourth industrial revolution, is a novel concept that can digitally transform the information and knowledge management function of service firms with smart automation, real-time high-volume data exchange and processing, and intelligent decision-making (Schwab 2017). It can help the service firms resolve critical problems of product and services including those related to the sustainable development goals and thereby the sustainability of the firms (Gaiardelli et al. 2021). I4.0 can be viewed as a collection of several advanced technologies such as Predictive Analytics, Cloud Computing, Radio-Frequency Identification, Machine Learning, Artificial Intelligence, Extended Reality, Additive Manufacturing, the Internet of Things (IoT) (Lee and Lee 2020), and many more. In general, these advanced and new-age technologies are collectively referred to as 'I4.0 technologies (I4T)'.

According to Moeuf et al. (2020), I4T pertaining to the flow of data, such as Cloud Computing, Big Data Analytics and IoT, are the most commonly used technologies in MSMEs owing to their simplicity and wide range of applicability compared to other I4T. With the limited number of resources that a service MSME possesses, beginning with the application of IoT can help them reap incremental benefits towards digitalization (Hansen and Bøgh 2021). Machine learning algorithms can be deployed to examine the X-rays, CT scans and photographs of internal organs in a far more precise and quicker manner across massive databases of images (Giger 2018). Wongchinsri and Kuratach (2016) present a detailed framework for using BDA techniques in credit card fraud detection. Organizations adopting I4T can optimally design the processes to reduce the wastage of resources thereby minimizing the operational costs (Vaidya et al. 2018) and enhancing their productivity by almost 50% (Caylar et al. 2016).

However, the difficulties and priorities of MSMEs are quite different from those of the larger firms (Masood and Sonntag 2020). Factors such as dearth of skilled and flexible labour, scarcity of financial capital, security and privacy of personal data, lack of knowledge of technologies, government policies, trust of users, reliability of service providers, and infrastructural issues are the barriers for MSMEs to adopt I4T in emerging nations like India, Nigeria, Sweden, and Mexico (Beheshti and Salehi-Sangari 2007; Otuka et al. 2014; Maldonado-Guzman et al. 2017; Khanzode et al. 2021). Thus, in service MSMEs of emerging nations, a practical inability in adopting the technologies that can optimally meet their requirements and serve the designated purpose exists.

Given that the capital structure decisions of service MSMEs are quite different from other types of industries (Serrasqueiro et al. 2011) and that service MSMEs have limited financial resources (Khanzode et al. 2021), selecting and investing in the most appropriate I4T becomes extremely crucial for MSMEs. Ghobakhloo (2018) and Sarvari et al. (2018) have stressed the importance of selecting the right I4T, but lack in providing specific inputs for selecting of correct I4T for service MSMEs. Similarly, Hamzeh et al. (2018) have attempted to create an I4T selection framework for manufacturing firms, but it does not specify the goals of a firm against which these technologies must be evaluated for selection. Thus, there exists a significant gap in the existing literature about identifying most suitable I4.0 for service MSMEs, especially for sustainability.

Most of the existing literature focuses on only a specific dimension or concept of sustainability, or a specific I4T (Ejsmont et al. 2020). Furstenu et al. (2020) have found that the current literature lacks theoretical and empirical research on the impact of I4.0 specifically on the social sustainability aspect. Even studies as recent as Azadi et al. (2021) have tried to assess the sustainability of service firms with just one I4T and with minimal focus on social and environmental side of sustainability. As I4.0 comprises various fundamental technologies, it becomes crucial to probe further and identify the influence that an individual digital technology posits on the sustainability of a system (Beltrami et al. 2021). There is a dearth of literature that explores the appropriate information and communication technologies (ICTs) for achieving the green initiatives of a service firm (Centobelli et al. 2017). Bai et al. (2020), after assessing the I4T for sustainability, have stated that future studies must try to assess the impact of all I4T on all the dimensions of sustainability, preferably with primary data and multi-criteria decision-making (MCDM) techniques. Furthermore, as suggested by Rha and Lee (2022) in the future scope of their detailed literature review on the digital transformation of service firms, studies on how post-pandemic business landscape will impact digitalization in the service industry must be conducted. Thus, a significant gap exists in the current state of literature about I4.0 and its impact on sustainability, especially for service MSMEs.

In this light, this study aims to address the two major gaps in the literature: (a) lack of studies regarding the impact of I4.0 on environmental and social aspects of sustainability, and (b) lack of a complete model and approach to the selection of I4T for service MSMEs for a critical goal. This study does so by assessing the most preferred I4T for adoption in service MSMEs along with an order of preference of these

technologies for enhancing sustainability in service MSMEs. The research question addressed by this study is as follows:

**RQ.** Given that MSMEs have limited resources, which I4T are most preferred to achieve sustainability in service MSMEs?

The remainder of the article is structured as follows. Section 2 describes the theoretical underpinnings for this study, discusses relevant literature pertaining to sustainability through I4T, and the use of I4T in the service industries. Section 3 describes the research design and methodologies applied in this study, followed by the application of these methods, analysis, and results in Sect. 4. Section 5 discusses the results and provides theoretical and managerial implications, followed by a conclusion in Sect. 6, and identification of certain limitations, and directions for future research in Sect. 7.

## 2 Theoretical background and literature review

### 2.1 Technology acceptance model (TAM) and extended TAM (TAM2)

To understand the adoption process of I4T in service MSMEs, it is important to understand the factors that support or hinder the acceptance of a technology. We found that TAM (Davis et al. 1989) is one of the most robust theories commonly utilized by researchers to study the process of technology adoption. According to TAM, the intention to use (ITU) a technology is determined by two beliefs, perceived usefulness (PU) and perceived ease of use (PEOU). The two beliefs mediate between external variables and the ITU. However, TAM does not specify the factors that influence the PU of the users. This deficiency of TAM was mended in its extended model, known as TAM2 (Venkatesh and Davis 2000). Several studies (Liébana-Cabanillas et al. 2018; Hamdani 2019; Talukder 2019) in the extant literature have used TAM2 as their theoretical underpinning for studying the technology acceptance in service firms. Studies (Nasser and Prabhakar 2017; Najib and Fahma 2020) in the context of service MSMEs have also shown that PU has effect on ITU, and consequently on the technology acceptance. This study builds its scope and research question by deconstructing the definitions of two of the antecedents of PU in TAM2 and deriving their extended meanings. The subsequent paragraphs shall explain this in detail.

TAM2 provides empirically established determinants of PU (see Fig. 1), viz. (a) subjective norm, (b) image, (c) job relevance (JR), (d) output quality (OQ), and (e) result demonstrability. All the determinants have been observed to have a positive influence on PU. JR is defined as “an individual’s perception regarding the degree to which the target technology is applicable to his/her job” (Venkatesh and Davis 2000, p. 191), whereas OQ is defined as an individual’s perception of “... how well the system performs those tasks, which ... match their job goals” (Venkatesh and Davis 2000, p. 191).

Probing further into the definition of JR, we can say that to apply the TAM2 model in any context, the ‘target technology’ which an individual (manager/owner/proprietor of service MSMEs) has the perception of being applicable and its

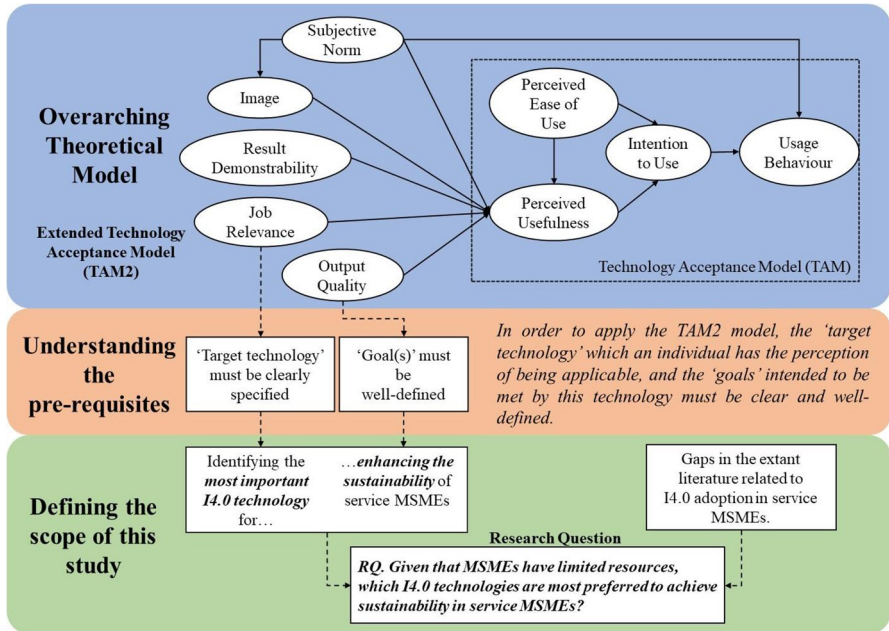


Fig. 1 Theoretical background of this study

applicability must be well-specified. Similarly, deconstructing the definition of OQ reveals that the ‘goals’ intended to be met by this technology must also be clear and well-defined. Thus, we infer that to study the I4T acceptance in service MSMEs, we first need to (a) clearly identify the most relevant I4T (target technology) for service MSMEs, and (b) clearly specify the goals that are to be met. Only then can one apply the TAM2 model for further empirical investigation (see Fig. 1). Thus, the conception of the determinants of PU, specifically JR and OQ, helped us form the theoretical background for the research question of this study. Hence, based on the understanding of technology acceptance derived from TAM2, this study aims to identify the most important I4T (target technology) to achieve sustainability (goal) in service MSMEs by capturing the PU of several I4T using a combination of Fuzzy Delphi Method (FDM) followed by Analytic Hierarchy Process (AHP).

## 2.2 Sustainability through I4.0 in service industries

As the service MSMEs are quite different from the manufacturing MSMEs in several ways (Lejpras 2019), special attention needs to be paid to service MSMEs for enhancing the sustainability through I4.0. Several studies have presented the applicability of I4T for sustainability in service firms. Damoah et al. (2021) have examined the use of AI-drones to enhance the sustainability of healthcare supply chains in Ghana and found that use of AI-drones for emergency medical products have reduced the carbon footprint and noise pollution near hospitals. Consequently,

this shall lead to better socio-economic situations and decreased death rates, thereby enhancing the sustainability of hospitals. Del Vecchio et al. (2018) have shown the prowess of Big Data for initiating the innovation processes in developing sustainable digital tourism experiences by providing a longitudinal case study of a European tourist spot. Eskerod et al. (2019) have proposed certain drivers for the adoption of IoT by hotels for becoming sustainable by conducting exploratory case studies in high-end hotels of North America, thereby implying the prowess of IoT to enhance the sustainability of hotels.

In order to systematically study the influence of I4T on the sustainability of service firms, a total of 13 essential factors that determine the sustainability for service industries (Table 1) were adopted from the research conducted by Hussain et al. (2016), which empirically verified the essential factors for sustainable supply chain in service industries. Moreover, the study also emphasized the dearth of research in sustainable service industries and the exigency of different research studies on further understanding the sustainable supply chain in service industries, especially in Asian countries.

We then identified a total of 12 key I4T relevant for service firms. These technologies have not only been widely discussed in the literature but have also been adopted by several firms, keeping in mind the advantages that these technologies can offer in improving the business processes. These technologies are briefly discussed below.

**Table 1** Factors of sustainability in service firms

Dimensions of sustainability	Factors that enhance the sustainability of service firms
Environmental management	Complying with the applicable environmental laws and regulations. (E1)
	Communicating the environmental policies, practices and expectations are to all employees and suppliers in local or appropriate languages. (E2)
	Training the employees on relevant environmental targets. (E3)
Social responsibility management	Complying with the corporate responsibility policy or statement of commitment for labour, health, and safety standards. (S1)
	Developing management systems to maintain relations with community stakeholders. (S2)
	Complying with the applicable social laws and regulations. (S3)
Health, safety and risk management	Communicating the use and disposal of hazardous materials to the workers clearly in language(s) they understand. (H1)
	Developing a well-defined emergency response plan. (H2)
	Conducting emergency drills for workers regularly. (H3)
	Having well-stocked, unlocked first aid stations at different sites. (H4)
Customer management	Having well-defined communication standards and protocols. (C1)
	Using multiple channels (internet, kiosk, mobile devices, or other innovative channels) to deliver the information/services. (C2)
	Easy and accurate accessibility to the up-to-date customer information by staff through different channels. (C3)

### 2.2.1 Big data and analytics

Big Data and Analytics (BDA) techniques such as text mining and analytics helps the firms to churn out meaningful information from the data collected from customers. Studies such as Schaeffer et al. (2014) and Donnelly et al. (2015) have also highlighted how BDA can help MSMEs derive value from the collected data, thereby implying the effectiveness of BDA in MSMEs. Another application of BDA is identifying abnormal online behaviour of bank accounts. Wongchinsri and Kuratach (2016) present a detailed framework for using BDA techniques in credit card fraud detection. Thus, BDA holds tremendous potential to improve the sustainability of service MSMEs.

### 2.2.2 Robots

According to the literature on service management, both the server and the client of a particular service are supposed to be humans. With the technological advancement in the field of robotics, machines can also provide services. The recent COVID-19 pandemic has compelled many hospitality and tourism organizations to swiftly come up with touchless solutions with the help of robots. Robots can reduce the workload of the frontline workers in hospitality and healthcare sector, thus enabling social distancing of humans and keeping them away from potential infection (Belanche et al. 2020a, b). Certain humanoid robots can also lead to better customer comfort and satisfaction (Becker et al. 2022). Thus, robotic technology holds tremendous potential to improve the sustainability of service MSMEs.

### 2.2.3 Internet of things

IoT finds immense applications in service industries (Rha and Lee 2022). Various studies have addressed the technological and administrative aspects of hospital IoT implementation. In addition to a systematic study of the network architectures, Dhanvijay and Patil (2019) recommend an IoT healthcare system using the Wireless Body Area Network. Ghosh et al. (2016) have elegantly suggested an Arduino and Phidgets Interface Kit architecture for concerned caregivers in the home who can communicate to physicians over the Internet and support doctors in monitoring patients' conditions remotely. Hence, IoT technology holds tremendous potential to improve the sustainability of service MSMEs.

### 2.2.4 Simulations

Simulations can be used for the training and examination of pilots by the airline companies. Flight simulators can deliver the trainees secure conditions to rehearse in otherwise high-risk exercises and increase the quality of their training by eliminating obstacles pertaining to inclement climate conditions, airspace obligations, and unavailability of flight instructors, reducing the costs involved with training, environmental impact, and serious accidents (Salas et al. 1998). The application of simulation in surgery has developed significantly in the last decade and has become

normal in today's surgical training, proving to be an essential instrument in the attaining clinical and surgical skills and knowledge (Scott et al. 2008). Thus, simulations can improve the sustainability of service MSMEs to a great extent.

### 2.2.5 Cyber security

With the increased connectivity and use of standard communications protocols that come with I4.0, the need to protect critical industrial systems and manufacturing lines using Cyber Security (CS) increases dramatically. As a result, secure, reliable communications and sophisticated identity and access management of machines and users are essential. Information is the most precious property in the twenty-first century. Customers are generally worried about the theft of their privacy and identity. One of the major areas where CS has tremendous potential for applications is the banking sector. The competency of a bank is often judged in terms of the network security of its services. As most of the banking services take place over digital media, having a strong CS is directly linked with the economic sustainability of the firms (Ula et al. 2011).

### 2.2.6 Cloud computing

Cloud Computing (CC) refers to remote access with an extremely fast response to data stored in an external environment, through the IoT. Lately, the CC technology has gained popularity in technologies for service industry owing to its advantages like scalability, mobility, security, and readily available storage, and applications to users. CC has materialized as an essential pillar of IoT healthcare systems. One of the major benefits of CC is its adroitness in the propagation of well-structured information to health professionals, nurses, and patients, thereby reducing the chances of mishandling medical records (Riazul Islam et al. 2015). Thus, CC can significantly benefit healthcare services and applications, thereby enhancing their sustainability.

### 2.2.7 Additive manufacturing

Additive Manufacturing, also known as 3D printing, can produce small batches of custom products that offer building advantages, such as in the design of complex parts by depositing a material layer-upon-layer. Models created by additive manufacturing can help train the medical students or doctors before a surgery to save time during operation. Such models can be custom 3D printed as per the requirement (Yap et al. 2017). Tissues and organs can also be cultivated using 3D printed scaffolds by integrating them with a living cell immersed in hydrogel. Thus, additive manufacturing can greatly help service firms like hospitals to become sustainable.

### 2.2.8 Augmented reality

Augmented Reality (AR) expands the information in the environment surrounding a human, allowing the human to interact with virtual objects that co-exist simultaneously with a physical environment in a virtual way, in the same space as the real



environment (Vaidya et al. 2018). This technology can find its applications in education and training institutes for skills requiring a high level of dexterity, such as training of aircraft pilots (Schaffernak et al. 2020). Virtual Reality, a technology closely related to AR, finds its applications in enhancing the positive emotional reactions and levels of psychological and behavioural engagement of the guests in the hospitality sector (Flavián et al. 2021) and in improving the customer experience in the tourism sector (Flavián et al. 2019). Thus, AR can significantly contribute to the sustainability of the services sector.

### 2.2.9 Cyber-physical systems

Cyber-Physical Systems (CPS) are systems that combine statistics and computational approaching with real-time data extracted from physical systems, to approach the response of a structure under various scenarios, intending to indicate the best decision. In fact, they are transforming technologies for managing systems interconnected between physical and computational resources, by leveraging the interconnectivity of intelligent, resilient, and self-adaptive machines (Ahuett-Garza and Kurfess 2018). Such technology finds its application in improving the accuracy of real-time navigation and software security in aviation, and improving the patient-monitoring systems, internal security, and internal communication within the hospitals (Dey et al. 2018).

### 2.2.10 Radio-frequency identification

Radio-Frequency Identification (RFID) technology tracks material in real-time and locates objects in the value chain precisely, resulting in reduced search time and improved process transparency. Using RFID tagging techniques in retail stores can significantly elevate the shopping experience of customers (Choi et al. 2015). RFID based tagging can also help install an automated shelf-replenishing system using the data collected from the purchase, sales and inventory. RFID can find its application in industries like retail (Huang 2018), and healthcare (Lee 2019). Thus, RFID has immense potential to make retail firms more sustainable.

### 2.2.11 Artificial intelligence

Artificial Intelligence (AI) technology holds tremendous potential across all areas of medicine, from surgery to psychology to radiology (Flavián and Casaló 2021). Machine learning algorithms can be deployed to examine the X-rays, CT scans, and photographs of internal organs in a far more precise and quicker manner across massive databases of images (Giger 2018). AI finds a remarkable application in the development of smart medical equipment such as devices meant for tracking and regulating oxygen saturation levels, insulin levels, blood pressure etc. (Metcalf et al. 2016). Thus, AI has massive potential to revolutionize service industries like healthcare, banking, and e-commerce, thereby making them more sustainable.

## 2.2.12 Autonomous vehicles

Autonomous Vehicles (AV) is a technology that transports objects within an organization's value chain automatically, minimizing human mistakes and empty trips. One of the most suitable applications of AVs is in the indoor logistics of a firm, such as hospitals (Pedan et al. 2017) and the ground operations of airlines (Bijjahalli et al. 2017). In such an environment, several AVs must work in high coordination and control for the completion of tasks such as dispatching, scheduling, and routing. Hence, AVs can prove to be a suitable technology in improving the sustainability of certain service firms.

## 3 Research methodology

### 3.1 Research design

To address the research question posed in this paper, the following research design was adopted (Fig. 2):

#### 3.1.1 Step I: literature review

Firstly, a detailed literature review was performed to identify the I4T that can be applicable in the service firms and factors that impact the sustainability of service firms. Thereby, a total of 12 I4T and 13 factors for sustainability (as discussed in Sect. 2.2) were identified from the extant literature.

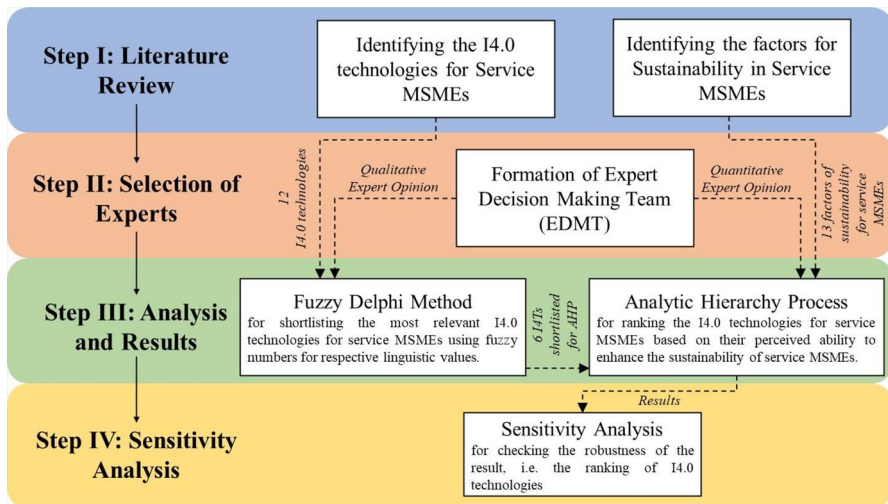


Fig. 2 Research design

### 3.1.2 Step II: selection of experts

An expert decision-making team (EDMT) was formed to obtain practitioners' views on I4T. The experts were selected using a special kind of purposive sampling method known as the expert sampling method. In such a sampling method, the researcher determines the required sets of skills or expertise and accordingly finds experienced and knowledgeable respondents who can provide relevant input for the issue at hand (Bernard 2017). When the area of research is relatively new and there is a dearth of extremely expert people and observational evidence in the area, this kind of sampling is immensely suitable as it does not prescribe a minimum number of participants for analysis (Etikan 2016).

### 3.1.3 Step III: analysis and results

The experts were then asked to shortlist the most relevant I4T for service MSMEs from the 12 I4T identified from the literature. Thus, FDM was applied to shortlist a total of 6 I4T. With the help of AHP, these technologies were then prioritised based on their perceived ability to enhance the sustainability of service MSMEs, given by the 13 factors of sustainability. The results provided us with ranks of I4T.

Although the traditional MCDM techniques require pinpointed responses to derive the results, it is nearly impractical to use precise weights for real-life scenarios (Chen et al. 2006). The advantage of applying the FDM-AHP methodology is that it uses fuzzy numbers to record the responses of experts, which is apt for considering the inherent ambiguity and uncertainty present in the human psyche. Studies (Chen and Wang 2010; Chen et al. 2018) have demonstrated the prowess of FDM-AHP methodology in the prioritization of alternatives across various domains of services industry. Thus, the FDM-AHP methodology is suitable for addressing the aims of this study as well.

### 3.1.4 Step IV: sensitivity analysis

Finally, to check the robustness of the obtained results, sensitivity analysis of the results was performed by changing the weights of the criteria obtained during the AHP analysis.

## 3.2 Fuzzy Delphi method (FDM)

In the conventional Delphi method, proposed by Dalkey and Helmer (1963), the expert opinions help determine the relevant alternatives. However, the opinions of experts cannot be quantitatively pinpointed in real-life situations, especially in case of a relatively newer area of research, owing to a certain amount of uncertainty or ambiguity in the knowledge and expertise of the expert. This problem can be solved by introducing fuzzy set theory, which helps classify qualitative judgements such as 'important' or 'very important' into fuzzy numbers. Hence, a special kind of Delphi

method known as FDM, developed by Ishikawa et al. (1993) by incorporating fuzzy set theory, was used to record the expert opinions. The advantages of the FDM for collecting group decision are threefold: (a) the effect of each expert opinion can be included to arrive at a single consensus, (b) the fuzziness inherent in humans, uncertainty, and subjectivity can also be incorporated, and (c) the number of investigations, cost, and time can be reduced significantly. The steps for performing FDM analysis have been explained in detail in section B of [Appendix](#).

### 3.3 Analytic hierarchy process (AHP)

The AHP MCDM technique was established by Saaty (1980) in order to obtain the relative priorities of a group of alternatives. The major advantages of this technique are that (a) it enables the consolidation of a set of intangible qualitative decisions vis-à-vis tangible quantitative criteria, and (b) it deconstructs a highly complex MCDM problem into a simpler decision hierarchy with a minimum of three levels: alternatives of the decision at the bottom, criteria in the middle, and the ultimate aim of the problem at the top which helps in making a pairwise comparison from the second level of the hierarchy to the lowermost level to obtain the relative importance of the elements of one level based on the elements in the immediately upper level of the hierarchy. Hence, AHP is deemed to be suitable for addressing the objectives of this study as well. The steps for performing AHP analysis have been explained in detail in section C of [Appendix](#).

## 4 Analysis and results

### 4.1 Expert selection process

A total of 18 experts, who are managers and/or proprietors at various service MSMEs, were selected using the expert sampling method. It can be inferred from the designations and experience of the respondents (Table 2) that they are well-qualified to be an expert for this study. However, we additionally confirmed their knowledge and understanding of the I4T and sustainability and briefed them about the purpose of the study. They were provided with the various aspects of sustainability and how they affect the competitiveness of a firm. They were also apprised about the various I4T and their applications. Further, they were encouraged to ask and clarify any of their queries regarding the concepts and technologies. Thus, it was ensured that the participants had sufficient knowledge and the background to justify the results of the study.

### 4.2 Application of FDM

After identifying the I4T from the extant literature, the experts were provided with a FDM questionnaire for shortlisting the most relevant I4T for service MSMEs. The responses thus collected were processed as described in Sect. 3.2. The threshold

**Table 2** Profile of the experts

Characteristics	Position	Frequency	Percentage (%)
Job title	IT manager	7	38.89
	Associate consultant	6	33.33
	Associate physician	2	11.11
	Supply chain manager	1	5.56
	Senior software engineer	1	5.56
	Assistant manager	1	5.56
Experience (in months)	5–15	2	11.11
	16–25	5	27.78
	26–35	5	27.78
	36–45	4	22.22
	45 +	2	11.11
Industry	IT	7	38.89
	Management consulting	6	33.33
	Healthcare	2	11.11
	Others	3	16.67

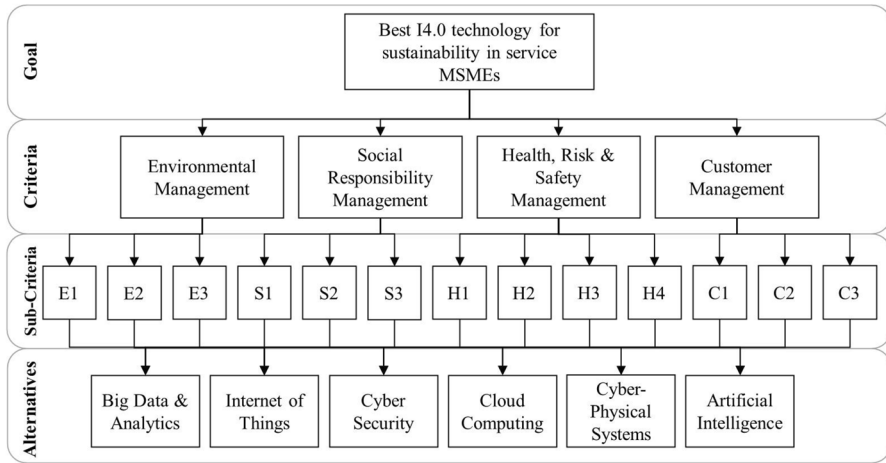
value  $A$  for our study turned out to be 0.59. Hence, only the I4T with  $A_j$  values greater than 0.59 were shortlisted for the next stage of analysis. Thus, a total of 6 I4T were shortlisted: BDA, IoT, CS, CC, CPS, and AI (Table 3).

### 4.3 Application of AHP

First, the complex MCDM problem was structured into a decision hierarchy as shown in Fig. 3. Then, the experts were asked to make pairwise comparison of the criteria to obtain the weights for AHP. The criteria vs criteria matrices of

**Table 3** Results of FDM

I4T	FDM score	Decision
Big data and analytics	0.803	Shortlisted
Robots	0.506	Not shortlisted
Internet of things	0.789	Shortlisted
Simulations	0.573	Not shortlisted
Cyber security	0.665	Shortlisted
Cloud computing	0.882	Shortlisted
Additive manufacturing	0.333	Not shortlisted
Augmented reality	0.333	Not shortlisted
Cyber-physical systems	0.617	Shortlisted
RFID	0.576	Not shortlisted
Artificial intelligence	0.720	Shortlisted
Autonomous vehicles	0.333	Not shortlisted



**Fig. 3** Decision hierarchy for application of the AHP technique. Please refer to Table 1 for the full names of sub-criteria (E1 through C3)

all the experts were consolidated in to one matrix (Table A4, Appendix) using the geometric mean of all the corresponding values, as suggested by Aczél and Saaty (1983). The consistency ratio of the criteria weights turned out to be  $8.74\% < 10\%$ . Hence, the weights can be used for further analysis.

The experts were then asked to make pairwise comparison of alternatives, i.e. the I4T, vis-à-vis each criterion i.e. the factors of sustainability, using the standard AHP scale (Table A3, Appendix). Evaluating pairwise comparison matrices of alternatives for all the criteria provided us with 13 sets of normalized principal eigenvectors (Table A5, Appendix), one set for each factor of sustainability. Finally, the normalized principal eigenvectors matrix was cross multiplied with the weights to obtain the score of preference for each technology. The order of preference of I4T for sustainability in service MSMEs thus obtained (Table 4) is as follows: AI > BDA > IoT > CPS > CS > CC.

**Table 4** Ranks of I4T

I4T	AHP score	Rank
Artificial intelligence	0.595	1
Big data and analytics	0.590	2
Internet of things	0.565	3
Cyber-physical systems	0.514	4
Cyber security	0.446	5
Cloud computing	0.383	6

#### 4.4 Sensitivity analysis of the results

The criteria weights in an MCDM study are generally determined by the perception of the experts, which may sometimes lead to a certain degree of subjectivity in the results. Hence, to assess the robustness of the results, sensitivity analysis of the results was performed by varying the criteria weights one at a time, such that the sum of the weights remained unity. The criteria weights were tweaked within the range of  $\pm 60\%$ , with a step size of 20%.

The sensitivity analysis shows that the results are highly robust for the criteria E1, E2, S1, S2, S3, H3, C2, and C3 up till +60% change in weights, and for the criteria E2, E3, S1, S3, H1, H2, H4, and C1 up till -60% change in weights. The ranks of the top three alternatives have not changed in the sensitivity analysis of most of the criteria weights. Hence, the results of the FDM-AHP methodology are sufficiently robust.

### 5 Discussion

It is evident from the results that AI, BDA, and IoT are the top three preferred I4T for the goal of achieving sustainability. The sensitivity analysis of the results demonstrated the robustness of the results. The findings of this paper are aligned with the findings of Moeuf et al. (2020), who propose that I4T pertaining to the flow of data, such as BDA and IoT, are the most commonly used technologies in SMEs owing to their simplicity and wide range of applicability compared to other I4T. Studies such as Hansen and Bøgh (2021) have shown that with the limited number of resources that an MSME possesses, beginning with the application of IoT can help them reap incremental benefits towards digitalization. Similarly, studies like Ushada et al. (2017) provide some ingenious and cost-effective ways in which MSMEs can begin to reap the benefits of AI. Studies such as Schaeffer et al. (2014) and Donnelly et al. (2015) have also highlighted how BDA can help MSMEs derive value from the collected data, thereby implying the effectiveness of BDA in MSMEs. Thus, the results obtained in our study not only align with the existing literature, but also augment the existing literature with a more pinpointed and well-defined analysis of the issue.

On further probing into the probable reasons as to why the experts from service MSMEs must have gravitated towards these three technologies, we found a novel perspective. According to the TAM2, the managers tend to select the technologies based on their PU, which is in turn determined by JR, OQ and PEOU. For instance, in a healthcare setup, doctors perceive that having an algorithm based on AI for detecting tumours from a photograph can significantly reduce their burden of manually scanning through the images, thereby saving their time. Further, with the domestication of technological gadgets like computers and smartphones, most of the doctors, even in MSMEs, nowadays are well versed with them, making it easier for the doctors to use such technologies. Thus, they very well acknowledge the perceived usefulness and ease of use of the system. Similarly, consultants in a management consulting firm would like to have a ready reckoner of all the important nuances of a case, or would like to find out the words, sentences or phrases which

drive the overall sentiment of a report or an article. Such tasks can be easily performed by an algorithm based on Text Mining, a sub-discipline of BDA. Likewise, in restaurants and retail chains, simple tools like IoT sensors, in association with algorithms based on AI and BDA, supported by wireless networks can help in alerting the managers before a particular item needs to be replenished, identifying the key areas in a retail chain, and optimizing the arrangements of products in those areas that can lead to more sales, and maintaining a smooth and accurate flow of information from the order desk to the kitchen. In all these cases, the managers have knowingly or unknowingly acknowledged the PU of the technology, driven by JR, OQ and PEOU. Hence, although subconsciously, the experts must have gravitated towards the three technologies based on these factors.

### 5.1 Major contributions

While understanding the I4T adoption in service MSMEs, we came across certain significant gaps in the literature, viz. (a) lack of studies regarding impact of I4.0 on environmental and social aspects of sustainability, and (b) lack of a proper and complete model for selection of I4T in service MSMEs for a critical goal. This study tries to address the gaps and makes the following major contributions to existing literature:

Firstly, the existing studies (Ghobakhloo 2018; Hamzeh et al. 2018; Sarvari et al. 2018) have tried to address the I4T selection problem but fall short in providing pinpointed approach or a well-defined goal for which the I4T must be selected. Moreover, most of the studies of such kind are heavily focussed on manufacturing firms rather than service firms. A significant gap exists in the existing literature about identifying the most suitable I4.0 for a well-defined goal, especially in service MSMEs. With the limited financial resources that service MSMEs have, selecting and investing in the most appropriate I4.0 technology to help them achieve a critical goal like sustainability becomes crucial. This study thus contributes to the existing literature and tries to address this gap by identifying a suitable, well-defined, and critical goal—sustainability—for which the I4T must be selected in service MSMEs. Further, the research design in this study can be used as a framework for assessing the I4T against other well-defined goals.

Secondly, as I4.0 comprises of various fundamental technologies, it becomes crucial to further understand and identify the influence that an individual digital technology posits on the sustainability of a system (Beltrami et al. 2021). Existing studies in the area of sustainability and I4.0 (Centobelli et al. 2017; Ejsmont et al. 2020; Furstenuau et al. 2020; Azadi et al. 2021) have dealt with either a specific dimension of sustainability, or a specific I4T. This study not only considers all the I4T relevant for service industries, but also considers all the dimensions of sustainability in service MSMEs to assess the PU of each technology using primary data and MCDM techniques, as suggested by Bai et al. (2020). Moreover, by considering sustainability, which is one of the most pressing issues for the service MSMEs to stay globally competitive after the COVID-19 pandemic, this study also tries to address the suggestions of Rha and Lee (2022) to study the digitalization of service landscape post



the pandemic. This study should also be seen as a steppingstone in the holistic study of I4.0 and sustainability in service MSMEs. The research design developed for this study can also be utilised to study the impact of I4T on sustainability of other industries, as suggested by Beltrami et al. (2021), where the impact of I4T on sustainability have not been studied holistically.

## 5.2 Theoretical implications

To empirically analyse the I4T adoption, it becomes imperative to first identify the technology that is perceived to be most suitable for the sustainability. Previously, Mokhtar et al. (2020) have tried to study the diffusion of a single I4T, cloud computing, in Malaysian service SMEs but fall short to provide any robust support as to why cloud technology is suitable for Malaysian SMEs, why its diffusion must be studied over other I4T, and for what specific pressing goal (e.g. sustainability) it must be deployed. On the other hand, Mubarak et al. (2021) have empirically verified that I4.0 can help service SMEs achieve sustainability but fail to pin-point an I4T that can help achieve this most effectively. To the best of our knowledge, this is the first study to assess the applicability of I4T for sustainability in service MSMEs with the theoretical support of TAM/TAM2.

Further, this study contributes to TAM/TAM2, in the sense that it builds on the understanding derived from the pre-requisites of the determinants of PU (especially JR and OQ) and based on that, forms a well-defined research objective to prioritize the I4T for sustainability in service MSMEs. Thus, TAM2 acted as the overarching theory for this study, whereas the extended understanding of JR and OQ helped us define the scope and research question of the study. This study should be viewed as a starting point in the series of studies dealing with the application of TAM/TAM2 in the context of I4T in service MSMEs. Hence, one of the major theoretical implications of this study is the direction that it gives to the future researchers to conduct empirical research deploying TAM2 for the target technologies, such as AI, BDA, and IoT in service MSMEs.

## 5.3 Managerial implications

The MSMEs, especially in emerging economies, have a limited set of financial resources (Otuka et al. 2014; Maldonado-Guzman et al. 2017; Khanzode et al. 2021) which can be allocated to only those technologies that can enhance the sustainability of the firm in the best possible manner. Hence, it becomes crucial for the managers of the service MSMEs to identify the most suitable technologies that can serve the purpose in the best possible manner. The most relevant I4T identified and prioritised in this study shall not only optimize their returns on the financial resources allocated in technological innovation, but also decrease the probability of their business failing due to inappropriate technological investments. The findings of this study are also useful for the manufacturers and suppliers of the I4T for designing and refining their product development and marketing strategies strategically to target the service MSMEs. Thus, the marketing managers of a certain I4T supplier can strategize to

concentrate their resources more towards the marketing of AI, BDA and IoT over other I4T while targeting the service MSMEs.

Studies such as Belanche et al. (2021) have shown that better working conditions of the workers of a food delivery service firm lead to better customer perception about the firm, thereby highlighting the importance of social sustainability. With the effective use of IoT-based technologies, such as personalised health/function monitoring systems for humans as well as automobiles and wearable devices, the managers of the food delivery service firms can always keep a track of the vitals of their workers as well as their vehicles. Studies like Ushada et al. (2017) provide some ingenious and cost-effective ways in which MSMEs can begin to reap the benefits of AI. Studies such as Schaeffer et al. (2014) and Donnelly et al. (2015) have also highlighted how BDA can help MSMEs derive value from the collected data, thereby implying the effectiveness of BDA in MSMEs.

In the last few decades, the manufacturing sector has seen a huge transformation in terms of automation. This metamorphosis was mainly due to the objective nature of the processes of the manufacturing industries, that are majorly mechanized and have little room for subjectivity, making them straightforward to automate. However, in the service sector, the processes are subject to a high degree of contextual understanding of the environment. Hence, traditionally, it was nearly impossible to automate the service processes as opposed to the manufacturing processes. AI and BDA comprise of subdomains such as text and speech recognition, natural language processing, automated reasoning, neural networks, and machine learning, that have the capabilities to deal with the contextual and subjective nature of decision-making, very similar to those possessed by human beings. The sensors, actuators, controllers, and wireless networks act the way the sensory organs and the nervous system act in a human body. They collect and transmit the information from the surrounding environment for storage and processing. In this case, the information gathered from the elements of IoT is transmitted to a centralized database of the system, which acts the way the hippocampus acts in a human body. The algorithms based on AI can use the information stored in the data to identify patterns, correlations, derive conclusions from them, and train itself to act accordingly if such a situation arises in the future. This is like the human brain that deals with logic, cognition, and consciousness in general. Thus, when these three technologies come together, they form an information processing and decision-making system that is very similar to that of human beings. Hence, one of the major managerial implications is to leverage the power of these three technologies in combination, such that each technology can complement the others.

## 6 Conclusion

The service MSMEs are one of the crucial industries of any economy and more so of emerging economies. Therefore, focussing on the longevity and global competitiveness of the MSMEs is very important. The idea of sustainability of service firms, which is a strong determinant of the competitiveness of a firm and are globally well known in the field of operations and production management, are pretty alien to

most of the managers of MSMEs of developing economies. This poses a threat to their survival in the global competition. I4.0 has the potential to improve the sustainability of service MSMEs, but the literature revealed that there are several barriers, especially the lack of financial resources that hinder the managers of MSMEs to adopt the I4T. Thus, it becomes important to understand the specific needs of a service MSMEs and prioritize the I4T that can cater to these needs and enhance their sustainability in the best way possible. Hence, the most preferable I4T for achieving sustainability in service MSMEs were identified using a combination of two methods – FDM and AHP. We find the order of importance of I4T for sustainability in decreasing order as: AI, BDA, IoT, CPS, CS, and CC. The sensitivity analysis of the results showed that the criteria weights are robust within the range of  $\pm 60\%$ .

## 7 Limitations and future scope

The area this paper deals with is pretty nascent and under-investigated. Concepts such as I4.0, I4T, and sustainability have been barely studied in the context of service firms (Centobelli et al. 2017). As the capital structure decisions of service MSMEs are quite different from other types of industries (Serrasqueiro et al. 2011), the difficulties and priorities of MSMEs are quite different from those of the larger firms (Masood and Sonntag 2020), and that service MSMEs have limited resources (Khanzode et al. 2021), studying the role, adoption, relationship, barriers, and opportunities of I4.0 and I4T in the context of service MSMEs, especially in the emerging economies, provides fertile research avenues. Thus, this area of research holds tremendous potential for future research.

This study has few limitations which can be addressed in the future. The findings of this study are generalizable across the Indian service MSMEs, as the sample of experts hail from several Indian service MSMEs. However, the generalizability of the findings in other contexts are yet to be validated. In future, researchers can perform similar studies in other emerging economies to compare their findings with those of this study and validate it.

As suggested by Rha and Lee (2022) in the future scope of their detailed literature review on the digital transformation of service firms, studies on how post-pandemic business landscape will impact digitalization in the service industry must be conducted. In future, researchers can try to analyse the impact of the pandemic on the service business landscape, especially on the consumer preferences, from the perspective of digital technologies, the barriers in their adoption, and the opportunities that come with it.

The purpose of this study is to find the most suitable I4T that can improve the sustainability of service MSMEs. However, the goal of service MSMEs might vary from one economy to the other. Future studies can try to develop I4T selection frameworks for achieving different kinds of goals. From a methodological standpoint, in future, other methods such as fuzzy technique for order preference by similarity to ideal solution, fuzzy data envelopment analysis, and fuzzy analytic network process can also be used to compare the results.

From a conceptual standpoint, this study exists when the I4T adoption is in its nascent stage, especially in emerging economies. Therefore, the picture captured through this study might be completely different from when there will be sufficient diffusion and adoption of I4T far and wide in emerging economies. Hence, studies in future can try to record and comprehend the evolution of technology adoption process from its conceptualization to actuation, and based on this, try to devise road-map to adopt I4T in service MSMEs.

This study prioritizes the I4T from the perspective of managers and proprietors of service MSMEs. Studies in future can augment this study by adding the perspective of consumers as well in prioritizing the technologies, as consumers are an integral part of any service ecosystem. The researchers can also aim to validate the managerial findings of this study by implementing the technologies in service industries as a case study.

Future studies can focus on developing frameworks for specific sectors within service industries that show how these technologies should be implemented, aimed specifically on the interoperability of technologies and optimization of the technological layout. Nonetheless, this study comes up with results that can pave the way for future studies to make service MSMEs more sustainable, productive, and globally competitive.

## Appendix

Please copy and paste the following link into your browser to view the full Appendix: <http://dx.doi.org/10.13140/RG.2.2.33782.68162>

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## Declarations

**Conflict of interest** Author A declares that he has no conflict of interest. Author B declares that he has no conflict of interest.

**Ethical approval** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

**Informed consent** Informed consent was obtained from all individual participants included in the study.

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