International EUropean Journal of Managerial Research
Dergisi (EUJMR)
ISSN: 2602 – 4179 / Cilt: 7/ Sayı: 13
Konferans Bildirisi

DIGITAL TWIN TECHNOLOGY AND DIGITAL ENTREPRENEURS: ON THE TRAIL OF DIGITAL TRANSFORMATION TOWARDS A SUSTAINABLE FUTURE[1]

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ABSTRACT

Digital twin technology enables the development of sustainable business models for digital entrepreneurs through factors such as product lifecycle optimization, waste reduction and carbon footprint reduction. In this way, digital entrepreneurs embrace the principles of sustainability in terms of both innovation and environmental responsibility and utilize the potential of digital twin technology in this context. In this context, it is important to explore how today's technological innovations and entrepreneurial spirit can serve as a tool to build a sustainable future and how digital twin technology and digital entrepreneurs can contribute to addressing environmental and social issues. The aim of the research is to examine digital entrepreneurs' approaches to digital twin technology and to evaluate these outputs from a sustainability perspective. For this purpose, digital entrepreneurs' perceptions of digital twin technology were evaluated with the technology acceptance model (TAM). As a result of the model tested with structural equation analysis, among the variables of TAM model; ease of use has a significant effect on perceived usefulness, perceived usefulness has a significant effect on attitude and intention, and attitude has a significant effect on intention. However, it was observed that ease of use had no significant effect on attitude.

Key Words: Digital Twin Technology, Digital Entrepreneurs, Sustainability, Technology Acceptance Model (TAM), Sustainable Development

JEL Codes: L26, O14, O32, Q01, Q56

ÖZ

Dijital ikiz teknolojisi, ürün yaşam döngüsü optimizasyonu, atık azaltımı ve karbon ayak izinin azaltılması gibi faktörler aracılığıyla dijital girişimciler için sürdürülebilir iş modellerinin geliştirilmesine olanak sağlamaktadır. Bu sayede dijital girişimciler hem inovasyon hem de çevresel sorumluluk açısından sürdürülebilirlik ilkelerini benimsemekte ve dijital ikiz teknolojisinin bu bağlamdaki potansiyelinden faydalanmaktadır. Bu bağlamda, günümüzün teknolojik yeniliklerinin ve girişimcilik ruhunun sürdürülebilir bir gelecek inşa etmek için nasıl bir araç olarak hizmet edebileceğini ve dijital ikiz teknolojisinin ve dijital girişimcilerin çevresel ve sosyal sorunların ele alınmasına nasıl katkıda bulunabileceğini araştırmak önemlidir. Araştırmanın amacı, dijital girişimcilerin dijital ikiz teknolojisine yaklaşımlarını incelemek ve bu çıktıları sürdürülebilirlik perspektifinden değerlendirmektir. Bu amaçla dijital girişimcilerin dijital ikiz teknolojisine yönelik algıları teknoloji kabul modeli (TAM) ile değerlendirilmiştir. Yapısal eşitlik analizi ile test edilen model sonucunda, TAM modelinin değişkenlerinden; kullanım kolaylığının algılanan fayda üzerinde, algılanan faydanın tutum ve niyet üzerinde, tutumun ise niyet üzerinde anlamlı bir etkiye sahip olduğu görülmüştür. Ancak kullanım kolaylığının tutum üzerinde anlamlı bir etkisinin olmadığı görülmüştür.

Anahtar Kelimeler: Dijital İkiz Teknolojisi, Dijital Girişimciler, Sürdürülebilirlik, Teknoloji Kabul Modeli (TAM), Sürdürülebilir Kalkınma

JEL Kodu: L26, O14, O32, Q01, Q56

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[1] *This study is a derivative of the paper of equal title, presented at the "9th International EMI Entrepreneurship & Social Sciences Congress".*

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INTRODUCTION

In the rapidly evolving landscape of technology and entrepreneurship, the quest for a sustainable future is more critical than ever. With the spread of the Industry 4.0 vision all over the world, businesses have entered a major transformation. With this transformation, new technologies such as big data, artificial intelligence, blockchain, internet of things, digital twin have developed at an increasing pace, making the processes and concepts related to the areas where these developments are experienced more important (Deng et al., 2021; Duman, 2022). In particular, digital twin technology and digital entrepreneurs have become an important research topic as a result of the rapidly increasing digital transformation and sustainability concerns in recent years.

The real-time digital link between the state of a physical object or process and a virtual representation with functional output is known as a digital twin (Catapult, 2021; Boyes and Watson, 2022). Digital entrepreneurship, as defined by Yaghoubi et al. (2012:1049), is a subset of entrepreneurship that includes digital goods and services as well as their distribution, workplaces, and/or combinations. Digital twin technology plays a crucial role in sustainability as it enables the virtual representation and real-time monitoring of physical processes and assets, leading to more efficient resource management and reduced environmental impacts (Wang et al., 2023; Yuce, 2023). On the other hand, digital entrepreneurs can provide innovative solutions to support sustainability. Using digital technologies, they can contribute to the development of sustainable products and services, increase the efficient use of energy and resources, and improve waste management. Therefore, digital entrepreneurs make important contributions to sustainability efforts (Gebhardt and 2022; Arjune and Kumar, 2023)

The technology acceptance model aims to explain and theoretically model how people or society accept a technology (Marangunić and Granić, 2015). According to the model, when an individual or a society encounters a new technology, they may have different ways of thinking about how and why to use this new technology. From this perspective, the study examines digital entrepreneurs' approaches to digital twin technology and evaluates them in terms of sustainability. And also, this research explores how today's technological innovations and entrepreneurial spirit can be used as a tool to build a sustainable future and so, seeks to answer the question of how digital twin technology and digital entrepreneurs can contribute to addressing environmental and social issues.

1. LITERATURE REVIEW

1.1. Digital Twin Technology

Digital twin technology was initially created by NASA to forecast aircraft structural behavior by analyzing digital models (Lu et al., 2020). The Apollo space program was the first program to employ digital twin technology, using two identical spacecrafts, with one on Earth designed to simulate and predict the conditions in space. The information obtained through digital twin technology had a profound impact on the design and performance optimization of equipment in various industries. Since the Earth vehicle and the space vehicle were designed as identical, they were referred to as twin twins (Biesinger et al., 2019: 355).

According to Jones et al. (2020: 36), a digital twin is a synchronized, real-time virtual replica of any process, product, or environment. Furthermore, as stated by Kritzinger et al. (2018), a digital twin is a virtual technology that replicates any modifications made to a physical asset (Özgüner and Ovalı, 2023: 450). In essence, a digital twin is a virtual replication of a physical entity or process that replaces its state with a functioning output (Boyes and Watson, 2022).

Digital twin technology is a technology with the ability to self-adapt and self-parameterize (Schleich et al., 2017). In this way, it enables the development of real models and can be used as a useful tool for optimization. It can benefit its users in many ways by making complex relationships definable. Considering the digital twin applications and features discussed by Kitain (2018 as cited in Alptekin and Türkmen, 2023:3), it is possible to say that this technology will be a guiding model for today and the future. *Features of digital twin technology*: evaluating decisions by analyzing existing data, analyzing the process and making performance evaluations, remote control, reducing costs, connecting with other systems and examining the relationships between them, solving possible problems that may occur in the future, making complex processes easy and understandable. As can be seen, creating a multidimensional digital twin of systems is important for effectiveness, efficiency, continuity and even sustainability.

1.2. Digital Entrepreneurship

The increasing possibilities in digital technologies have made digital entrepreneurship widespread and ushered in a new era in the field of entrepreneurship. There are many different definitions in the literature regarding the concept of digital entrepreneurship, which is defined by Yaghoubi et al. (2012) as the merger of the concept of entrepreneurship and information technology in its simplest form.

First, according to Yaghoubi et al. (2012:1049), digital entrepreneurship is a type of entrepreneurship that encompasses digital products, services, distribution, a digital workplace or combinations thereof. Rashidi et al. (2013) defined digital entrepreneurship as a field of entrepreneurship in which new technological tools such as the internet and information technologies are used for business purposes. Guthrie (2015:115) defines digital entrepreneurship as the act of selling digital products or services through electronic networks (Eyel and Sağlam, 2021:8).

Within the scope of digital entrepreneurship, some or all of the activities related to the traditional entrepreneurial process are carried out digitally. It is seen that three types of digital entrepreneurship can be mentioned according to the scope of the activities performed (Hull et al., 2007:296): Digital entrepreneurship can be divided into three types, each representing varying degrees of participation in the digital economy. *The first type is mild digital entrepreneurship*, where individuals or businesses enter the digital world as a complement to their more traditional operations. In this category, digital elements complement traditional business practices. *The second type is moderate digital entrepreneurship*, characterized by a significant emphasis on digital products, digital distribution methods, or other digital components within the business model. The existence of digital entrepreneurship at the intermediate level largely depends on the existence of digital infrastructure, without which the business model cannot survive. This level of digital engagement means that digital technologies are more deeply integrated into various facets of the enterprise. *The third type is extreme digital entrepreneurship*, where the entire business operates in the digital space. This includes digital production processes, digital products or services, digital advertising, digital distribution channels and digital interactions with customers. Companies in this category are at the forefront of the digital landscape, selling digital products and services, transforming existing digital products, and potentially transacting with digital currencies. The entrepreneurial experience for these ventures differs significantly from that of their more traditional counterparts.

The differences between traditional and digital entrepreneurship, as well as between the three types of digital entrepreneurship, can be observed through various lenses, such as ease of market entry, ease of production and storage of products, ease of distribution. the digital market, the nature of the digital workplace, the characteristics of digital products and services, and the level of digital commitment required. Each type represents different levels of commitment to and trust in digital technologies, shaping the entrepreneurial landscape in unique ways.

1.3. Why Extreme Digital Entrepreneurs and Relationship of Concepts with Sustainability

This study considers extreme digital entrepreneurs. This is because digital entrepreneurs are thought to focus on the most highly digitized processes, such as digital twin technology. Studying such entrepreneurs can help understand innovative practices that push the boundaries of digital transformation and shape future business models. At the same time, extreme digital entrepreneurs can have a significant impact on a number of important issues such as sustainability, competitive advantage, customer relationship management and other business processes. Hence, the choice of extreme digital entrepreneurs may indicate that the study aims to provide a more in-depth and pioneering perspective of digital entrepreneurship.

As you know, Sustainability refers to the practice of meeting the needs of the present without compromising the ability of future generations to meet their own needs. It involves balancing economic, social, and environmental factors to create a harmonious and enduring way of living.

Digital entrepreneurs, on the other hand, can provide innovative solutions to support sustainability. By using digital technologies, they can contribute to the development of sustainable products and services, enhance the efficient use of energy and resources, and improve waste management. Therefore, digital entrepreneurs are significant contributors to sustainability efforts. The concept of "digital twin" plays a crucial role in sustainability as it enables the virtual representation and real-time monitoring of physical processes and assets, allowing for more efficient resource management and a reduction in environmental impacts.

Numerous potential advantages of the digital twin are highlighted in the literature (Kumaş and Erol, 2021). These advantages include decreasing expenses and hazards, boosting productivity (Duman, 2022), enhancing service quality, strengthening security, and enhancing resilience (Pan and Zhang, 2021). Extreme digital entrepreneurs can therefore use the data gathered by the digital twin to inform their strategic and operational decisions when they integrate these benefits into their business processes (Uhleman et al., 2017; Negri et al., 2017; Kritzinger et al., 2018). The information and data that will be produced by the virtual representation and used by businesses will support sustainability, given the significance of proactive initiatives for a sustainable future (Özgüner and Ovalı, 2023).

2. METHODOLOGY

In the study, 'extreme digital entrepreneurs' were reached through judgmental sampling and an online survey was applied. The survey was conducted between July 14 and October 20, 2023. In the questionnaire form, the original technology acceptance model questions of Davis (1989) were adapted from the study of Wu et al. (2011) and used with a 5-point Likert scale. The sample was applied to individuals who sell on the digital market, who do not have any physical showroom and who declare that they carry out all their processes in the digital market. It was observed that respondents generally sell through social media and digital market environments. Since it is not easy to reach extreme digital entrepreneurs, there were no regional or sectoral restrictions.

2.1. Sampling Process

The questions were revised to address whether digital entrepreneurs would use digital twin technology in their sustainability activities. You can see sample questions below:

- I believe that digital twin technology will contribute to our sustainability efforts.
- I found it easy to implement digital twin technology in our sustainability activities in practice.
- I believe that using digital twin technology in our sustainability projects is very good.
- When digital twin technology is available in our sustainability efforts, I plan to use it regularly in the future.

The sample was applied to individuals who sell on the digital market, do not have a physical showroom, and declare that they carry out all their processes on the digital market. It was observed that the participants generally sell through social media and digital market environments.

Since it is not easy to reach extreme digital entrepreneurs, no regional or sectoral restrictions were made. Since these individuals already carry out all their transactions in the digital environment, *they were* *selected as a sample by assuming that they have high computer literacy and do not have problems in using information technologies*.

In addition, the participants were asked "do you know about digital twin technology" as the ***first control question*** and if their answers were yes, they were allowed to continue the survey.

As the ***second control question***, the steps of using the digital twin technology were explained one by one and the participant was asked "do you think you can follow these instructions and use this technology?" and if the answer was yes, they were allowed to continue the survey.

2.2. Findings

The demographic characteristics of the sample are as shown in the table below.

Table 1. Demographic Profile

		Frequency	**Percent**
Gender	Woman	79	24,8
	Male	231	72,6
Age	25-35	205	64,5
	36-46	92	28,9
	47 +	13	4,1
Experience	Less than 10 years	211	66,4
	More than 10 years	99	31,1
Education	High School	9	2,8
	University	279	87,7
	Master's degree	16	5,0
	PhD	6	1,9
Monthly income	200 thousand TL and below	106	33,3
	2001-300 TL	47	14,8
	3001-400 TL	43	13,5
	4001-500 TL	55	17,3
	5001-600 TL	23	7,2
	6001-700 TL	26	8,2
	7001 thousand TL and above	9	2,8
	Missing value	8	2,5
	Total	318	100

Research model and hypotheses are as follows:

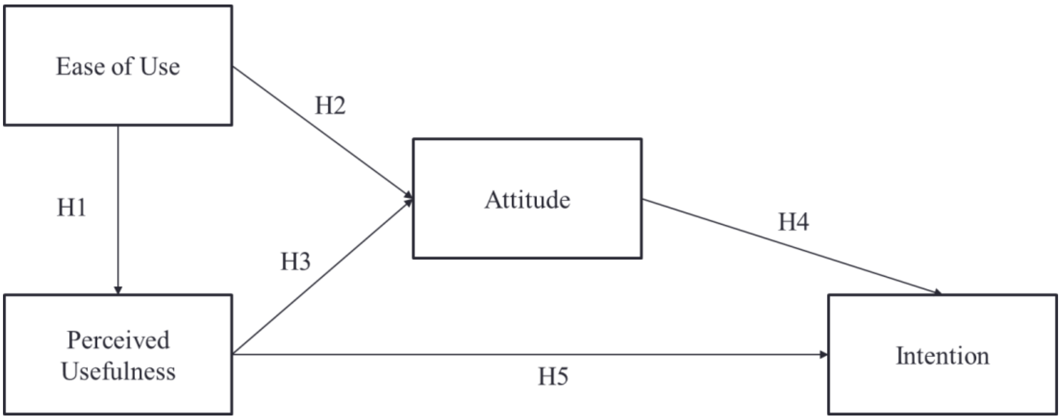

Figure 1. Original Technology Acceptance Model; Research Model

H1: Perceived ease of use has a significant effect on perceived usefulness.

H2: Perceived ease of use has a significant effect on attitude.

H3: Perceived usefulness has a significant effect on attitude.

H4: Attitude has a significant effect on intention.

H5: Perceived usefulness has a significant effect on intention.

Before the research model could be tested, explanatory and confirmatory factor analyses were conducted for the scales used. In addition, average variance extracted (AVE) and composite reliability (CR) values were examined.

Table 2. Exploratory Factor Analysis

Item	Rotated Component Matrix[a]					
		1	**2**	**3**	**4**	**Alpha**
Ease1	I found it easy to learn how to use digital twin technology.	,736				0,792
Ease2	I found it easy to implement digital twin technology in our sustainability activities in practice.	,708				
Ease3	I found it easy to operate digital twin technology in alignment with our sustainability goals.	,651				
Ease4	Overall, I found using digital twin technology in our sustainability projects easy.	,641				
Useful1	I believe that digital twin technology will contribute to our sustainability efforts.		,736			0,804
Useful2	I believe that digital twin technology will enhance the efficiency of our sustainability projects.		,650			
Useful3	I believe that using digital twin technology in sustainability initiatives will be effective.		,744			
Useful4	Overall, I find the use of digital twin technology in our sustainability efforts beneficial.		,775			
Att.1	I believe that using digital twin technology in our sustainability projects is very good.			,738		0,844

Att.2	In my opinion, using digital twin technology in sustainability efforts is highly desirable.			,797		
Att.3	It is much better for me to use digital twin technology for our sustainability goals.			,875		
Int.1	When digital twin technology is available in our sustainability efforts, I plan to use it regularly in the future.				,583	0,564
Int.2	Overall, I intend to use digital twin technology in our sustainability projects.				,740	
	KMO Measure of Sampling Adequacy 0,837 and Bartlett's Test of Sphericity 1412,605 df 78 and Sig. 0,000 Cumulative Variance %64,75					

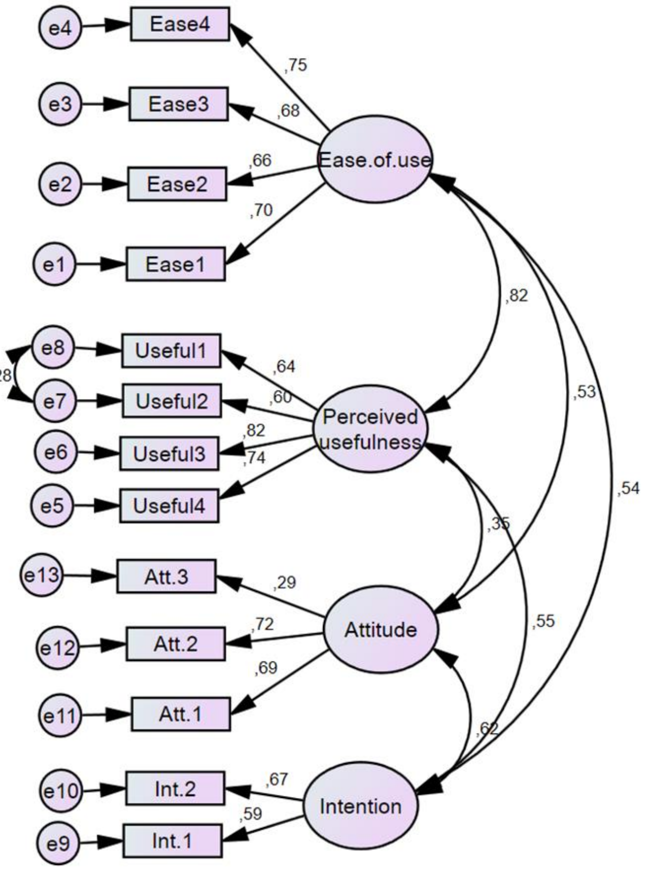

Figure 2. Confirmatory Factor Analysis

Table 3. Standardized Path Coefficient for Confirmatory Factor Analysis

Paths			**Std. Estimate**	**S.E.**	**t Value**	**p**	**Adj. R^2**
Ease1	<---	Ease.of.use	,697				,486
Ease2	<---	Ease.of.use	,657	,089	10,262	***	,431
Ease3	<---	Ease.of.use	,681	,080	10,603	***	,464

Ease4	<---	Ease.of.use	,751	,090	11,501	***	,564
Useful4	<---	Perceived_usefulness	,744				,407
Useful3	<---	Perceived_usefulness	,820	,086	13,080	***	,357
Useful2	<---	Perceived_usefulness	,597	,077	9,769	***	,672
Useful1	<---	Perceived_usefulness	,638	,081	10,450	***	,554
Att.1	<---	Attitude	,689				,085
Att.2	<---	Attitude	,723	,139	7,602	***	,523
Att.3	<---	Attitude	,292	,146	4,248	***	,475
Int.1	<---	Intention	,589				,347
Int.2	<---	Intention	,667	,171	6,434	***	,445

Table 4. Fit Values

Model Fit Indices	Model Fit Values	Acceptable Fit Values
X2	193,357	
df	58	
X2/df	3,334	1-5
RMSEA	0,086	0,05-0,10
AGFI	0,972	0,85-0,90
GFI	0,918	0,90-0,95
CFI	0,900	0,90-0,97
NFI	0,865	0,90-0,99

Table 5. CR and AVE Values for the Scales

	CR	AVE
Attitude	0,794	0,528
Ease of use	0,791	0,676
Perceived usefulness	0,796	0,676
Intention	0,705	0,571

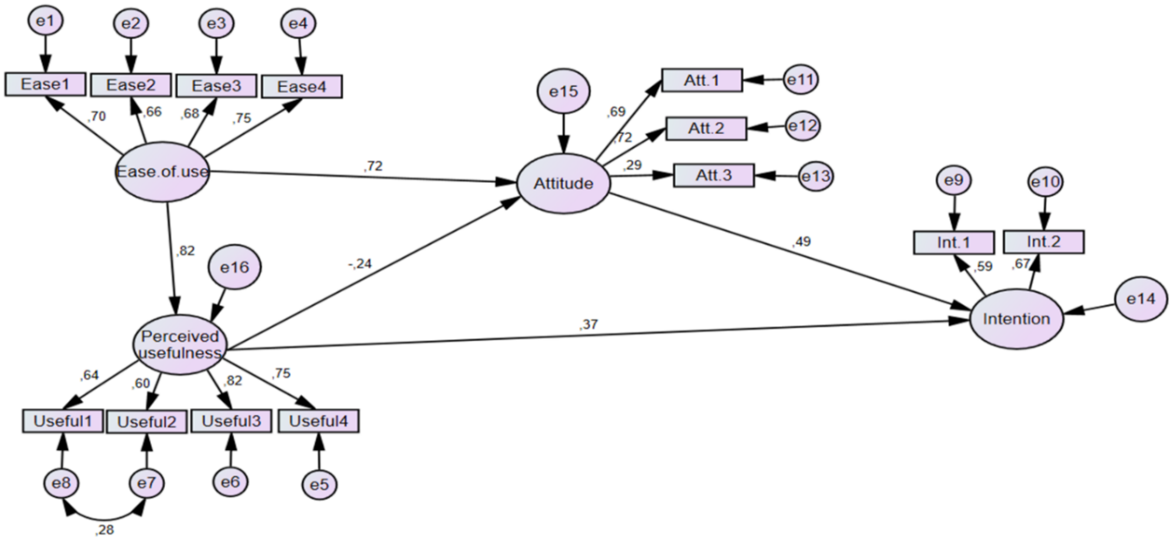

Figure 3. Path Diagram

Table 6. Standardized Path Coefficient for Reseach Model

Paths			Std. Estimate	S.E.	t Value	p	Adj. R^2
Perceived_usefulness	<---	Ease.of.use	,820	,100	9,807	***	,820
Attitude	<---	Ease.of.use	,721	,207	3,883	***	,721
Attitude	<---	Perceived_usefulness	-,241	,161	-1,397	,162	-,241
Intention	<---	Attitude	,487	,120	4,538	***	,487
Intention	<---	Perceived_usefulness	,368	,094	4,072	***	,368
Ease1	<---	Ease.of.use	,697				,697
Ease2	<---	Ease.of.use	,657	,089	10,260	***	,657
Ease3	<---	Ease.of.use	,681	,080	10,587	***	,681
Ease4	<---	Ease.of.use	,752	,090	11,503	***	,752
Useful4	<---	Perceived_usefulness	,745				,745
Useful3	<---	Perceived_usefulness	,822	,086	13,099	***	,822
Useful2	<---	Perceived_usefulness	,596	,077	9,757	***	,596
Useful1	<---	Perceived_usefulness	,637	,081	10,436	***	,637
Att.1	<---	Attitude	,691				,691
Att.2	<---	Attitude	,724	,140	7,540	***	,724
Att.3	<---	Attitude	,291	,145	4,222	***	,291
Int.1	<---	Intention	,588				,588
Int.2	<---	Intention	,669	,172	6,415	***	,669

Table 7. Fit Values

Model Fit Indices	Model Fit Values	Acceptable Fit Values
X^2	193,604	
df	59	
X^2/df	3,281	1-5
RMSEA	0,085	0,05-0,10
AGFI	0,873	0,85-0,90
GFI	0,918	0,90-0,95
CFI	0,901	0,90-0,97
NFI	0,865	0,90-0,99

3. FINDINGS AND DISCUSSION

This study aims to examine digital entrepreneurs' approaches to digital twin technology and evaluate these outcomes from a sustainability perspective. It is important to understand how today's technological innovations and entrepreneurial spirit can serve as a tool to build a sustainable future and how digital twin technology and digital entrepreneurs can contribute to environmental and social issues. In this context, the Technology Acceptance Model (TAM) was used to assess digital entrepreneurs' perceptions of digital twin technology. The results obtained can be expressed as follows:

Perceived ease of use has a significant impact on the perceived usefulness of a digital twin technology (H1 Accepted). This result suggests that how easy a digital twin technology is to use influences users' perception of how useful it is. Users may think that the easier a digital twin technology is to use, the easier it is to benefit from it. Perceived ease of use has a significant impact on attitude towards digital twin technology (H2 Accepted). This result suggests that the ease of use of a digital twin technology can positively influence users' attitudes towards it. Attitude has a significant impact on the intention to use digital twin technology (H4 Accepted). That is, as it is known, users' positive attitudes towards the use of digital twin technology can shape their intention to use it. Perceived usefulness has a significant impact on the intention to use digital twin technology (H5 Accepted): This result indicates that the extent to which users think that the use of digital twin technology is beneficial to them positively influences their intention to use this technology. If users think that digital twin technology will be beneficial to them, they may develop an intention to use it.

Hypothesis H3 "Perceived usefulness has a significant impact on attitudes towards digital twin technology" is rejected. It shows that for the sample of this study, how useful users perceive digital twin technology to be does not affect their attitudes towards it. While this result is surprising, it suggests that digital twin technology may not directly influence users' attitudes. Moreover, as Wu et al. (2011) pointed out in their study, it can be interpreted that the mediating effect of attitude variable with intention does not reveal a significant difference. Considering that in the extended technology acceptance models in the literature, models such as TAM2 and TAM3 do not include the attitude variable, this unsupported hypothesis may become more meaningful. Attitudes may be shaped depending on users' personal preferences, experiences or other factors, and it can be concluded that only the perceived benefit of a concept that can be considered complex such as digital twin technology is not sufficient to determine these attitudes.

CONCLUSION

The findings make a substantial contribution to comprehending the acceptance process of digital twin technology and user behaviors. In the context of sustainability, the following points can be elucidated:

Digital twin technology affords businesses the capability to virtually replicate physical processes, thereby promoting more efficient and environmentally-friendly operations. The heightened integration of this technology can facilitate the judicious use of resources and contribute to waste reduction. The results underscore the pivotal role of perceived ease of use in the acceptance of digital twin technology. The simplicity of use can expeditiously propel the adoption of technology, thereby facilitating the transition to sustainable business processes.

Contrary to our initial hypothesis, the results indicate that there may not be a direct relationship between perceived benefit and user attitudes. This suggests that additional factors may influence users to develop a positive attitude towards this technology for it to be adopted, especially in the context of sustainability. The results show that attitude significantly influences intention. This highlights the close association between the acceptance of digital twin technology and the adoption of sustainable business practices. Fostering a positive attitude is crucial for shaping intentions related to sustainability. This study has investigated the factors influencing the acceptance of digital twin technology and has unveiled important implications for sustainability.

On the other hand, to summarize all this briefly, it is possible to say that digital twin technology enables the development of sustainable business models for digital entrepreneurs through factors such as product lifecycle optimization, waste reduction and carbon footprint reduction. In this context, digital entrepreneurs adopt the principles of sustainability in terms of both innovation and environmental responsibility, and in this context, they can utilize the potential of digital twin technology.

These findings emphasize the potential of digital twin technology for digital entrepreneurs to develop sustainability-oriented strategies. However, the lack of an effect of ease of use on attitude suggests the need for a deeper understanding of technology acceptance processes and more specific strategies for entrepreneurs to adopt this technology. This study makes an important contribution to understanding how digital entrepreneurs approach digital twin technology from a sustainability perspective and to guide strategies in this area.

The biggest limitation of the study is that the digital twin technology is not yet very widespread and its cost cannot be clearly predicted; survey could not be applied directly to users. The second constraint is the possibility that the participants may have given biased answers to the control questions, that is, the possibility of respondent error. The study's sample size may be limited, and it may not fully represent diverse user groups. Future studies should aim for larger and more diverse samples to improve generalizability. The data collected in this study rely on self-reported responses, which could introduce response bias. Combining self-report with objective measurements could enhance the validity of the findings.

The study's findings are based on a specific context, and the results may not be general applicable. The contextual limitations should be acknowledged when applying the findings to other settings. While the study identifies relationships between variables, it does not establish causality. Future research may employ experimental designs to provide stronger evidence of causal relationships. The study primarily focuses on the technical and individual factors related to digital twin adoption. Future research should also explore the social and ethical implications of this technology.

Future research could focus on industry-specific applications of digital twin technology and how it influences sustainability practices. Different sectors may have unique challenges and opportunities for integrating digital twins into their operations. Conducting longitudinal studies to track the long-term impact of digital twin adoption on sustainability performance would provide valuable insights. This could help in assessing the sustainability benefits over time and identifying any changing dynamics.

Investigating how cultural factors influence the perception and acceptance of digital twin technology and its impact on sustainability could be a promising avenue. Cultural differences may play a role in shaping user attitudes and behaviors. Research could explore the effectiveness of user training and support programs in enhancing the acceptance of digital twin technology. Understanding the role of training in sustainability adoption is particularly relevant. The collaborative potential of digital twin technology could be studied further. Research could examine how businesses collaborate through shared digital twins and how this cooperation impacts sustainability efforts.

REFERENCES

Alptekin, G., & Türkmen, D. (2023). Dijital ikiz üzerine yapılan araştırmaların dergi yayınlarındaki eğilimlerinin görselleştirilmesi. *Açıköğretim Uygulamaları ve Araştırmaları Dergisi*, *9*(2), 1-30.

Arjune, S., & Kumar, V. S. (2023). Impact of Various Prospects Influencing Digital Entrepreneurship Sustainability. In *2022 OPJU International Technology Conference on Emerging Technologies for Sustainable Development (OTCON)* (pp. 1-6). IEEE.

Biesinger, F., Meike, D., Kraß, B., & Weyrich, M. (2019). A digital twin for production planning based on cyber-physical systems: A Case Study for a Cyber-Physical System-Based Creation of a Digital Twin. *Procedia CIRP*, *79*, 355-360.

Boyes, H., & Watson, T. (2022). Digital twins: An analysis framework and open issues. *Computers in Industry*, *143*, 103763.

Deng, T., Zhang, K., & Shen, Z. J. M. (2021). A systematic review of a digital twin city: A new pattern of urban governance toward smart cities. *Journal of Management Science and Engineering*, *6*(2), 125-134.

Duman, M. Ç. (2022). İşletmeler için yeni bir verimlilik teknolojisi: Dijital ikiz. *Verimlilik Dergisi*, 189-206.

Eyel, C. Ş., & Sağlam, H. (2021). Dijital dönüşüm ve girişimcilikteki değişim: Dijital girişimcilik. *Atlas Sosyal Bilimler Dergisi*, *1*(6), 7-20.

Gebhardt, L., & Hoelzle, K. (2022). Sustainable Entrepreneurs in Digital Business Ecosystems-Sovereignty vs. Business Model Potential. In *Academy of Management Proceedings* (Vol. 2022, No. 1, p. 16050). Briarcliff Manor, NY 10510: Academy of Management.

Guthrie, C. (2014). The digital factory: A hands-on learning project in digital entrepreneurship. *Journal of Entrepreneurship Education*, *17*(1), 115.

Hull, C. E. K., Hung, Y. T. C., Hair, N., Perotti, V., & DeMartino, R. (2007). Taking advantage of digital opportunities: A typology of digital entrepreneurship. *International Journal of Networking and Virtual Organisations*, *4*(3), 290-303.

Jones, D., Snider, C., Nassehi, A., Yon, J., & Hicks, B. (2020). Characterising the Digital Twin: A systematic literature review. *CIRP journal of manufacturing science and technology*, *29*, 36-52.

Kritzinger, W., Karner, M., Traar, G., Henjes, J., & Sihn, W. (2018). Digital Twin in manufacturing: A categorical literature review and classification. *Ifac-PapersOnline*, *51*(11), 1016-1022.

Kumaş, E., & Erol, S. (2021). Endüstri 4.0'da anahtar teknoloji olarak dijital ikizler. *Politeknik Dergisi*, *24*(2), 691-701.

Lu, Y., Liu, C., Kevin, I., Wang, K., Huang, H., & Xu, X. (2020). Digital Twin-driven smart manufacturing: Connotation, reference model, applications and research issues. *Robotics and computer-integrated manufacturing*, *61*, 101837.

Marangunić, N., & Granić, A. (2015). Technology acceptance model: a literature review from 1986 to 2013. *Universal access in the information society*, *14*, 81-95.

Negri, E., Fumagalli, L., & Macchi, M. (2017). A review of the roles of digital twin in CPS-based production systems. *Procedia manufacturing*, *11*, 939-948.

Özgüner, M., & Ovalı, E. (2023). Dijital İkiz Teknolojisinin İmalat Sektöründe Kullanımı Noktasında Kritik Öneme Sahip Başarı Faktörlerinin Swara Yöntemiyle Değerlendirilmesi. *Doğuş Üniversitesi Dergisi*, *24*(1), 449-462.

Pan, Y., & Zhang, L. (2021). A BIM-data mining integrated digital twin framework for advanced project management. *Automation in Construction*, *124*, 103564.

Rashidi, R., Yousefpour, S., Sani, Y., & Rezaei, S. (2013). Presenting a butterfly ecosystem for digital entrepreneurship development in knowledge age. In *2013 7th International Conference on Application of Information and Communication Technologies* (pp. 1-4). IEEE.

Schleich, B., Anwer, N., Mathieu, L., & Wartzack, S. (2017). Shaping the digital twin for design and production engineering. *CIRP annals*, *66*(1), 141-144.

Uhlemann, T. H. J., Lehmann, C., & Steinhilper, R. (2017). The digital twin: Realizing the cyber-physical production system for industry 4.0. *Procedia Cirp*, *61*, 335-340.

Wang, C., Miller, D., Gimona, A., Nijnik, M., & Jiang, Y. (2023). *An integration of digital twin technology, GIS and VR for the service of environmental sustainability* (No. EGU23-5626). Copernicus Meetings.

Yaghoubi, N. M., Salehi, M., Eftekharian, A., & Samipourgiri, E. (2012). Identification of the effective structural factors on creating and developing digital entrepreneurship in the agricultural sector. *African Journal of Agricultural Research*, *7*(6), 1047-1053.

Yuce, A. (2023). Digital Twins and Sustainable Developments in the Tourism and Hospitality Industry. In *Handbook of Research on Applications of AI, Digital Twin, and Internet of Things for Sustainable Development* (pp. 461-472). IGI Global.