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Research

Business readiness for dual transformation: an analysis of business capabilities for digital and sustainable transformation

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Abstract
In a dynamic business environment, the convergence of Digital Transformation and Sustainable Transformation has emerged as a comprehensive strategy for companies seeking to thrive in the modern era. For this transformation to successfully develop, the appropriate conditions must be present to carry out a process of digitisation and sustainability. Therefore, this research aimed to identify the readiness level of companies established in the city of Tijuana, Mexico, to adopt a dual transformation process. An analysis of the different digital and sustainable transformation models was carried out, and a self-diagnosis model was designed. Then, a quantitative instrument was applied to a sample of 148 small, medium and large companies in Tijuana between 2022 and mid-2023. The analysis consisted of a descriptive analysis of the data and a correlation analysis. It concludes that the elements that most explain the dual transformation are strategy, culture, organisational and technical capabilities. Likewise, the related factors are definition and communication, alignment, and scope of the objectives within the strategy; change management, knowledge and collaboration in the culture; within the organisation: leadership, processes and organisational structure; and finally in the technical capabilities data management, training and systems integration. The results of this research allowed us to identify and propose strategies to implement the dual transformation and increase the scalability and competitiveness of the adopting companies.

Keywords Digital transformation · Sustainable transformation · Organisational strategies

1 Introduction

The survival of small and medium-sized enterprises depends on their ability to face and take advantage of the two most impactful transformations derived from the fourth industrial revolution and the sustainability of communities: digital transformation and sustainable transformation [1]. Industry 4.0 is reconfiguring the economic dynamics by altering the drivers of competitiveness and development; on the one hand, due to environmental challenges and on the other hand, the digital and communications disruption in companies, so depending on criteria such as efficiency or cost reduction is no longer an option that guarantees success [2]. Currently, the demand for favourable working conditions, the technological surge and the sensitivity towards the environment have influenced the social perception of what a modern, fair and socially responsible company should be [3].

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This *dual transformation* trend was drastically accelerated by the effects of the COVID-19 pandemic [4]; according to the Development Bank of Latin America, 60% of small and medium-sized enterprises (SMEs) in the region were affected during this period, putting at risk the survival of more than 2.7 million companies. The health crisis and confinement had lasting effects on how consumers think and act [5]. One of the most significant changes is a greater trust and dependence on digital technology that has transformed how we work, shop and socialise [6].

E-commerce increased from 49 billion dollars in 2018 to $132 billion in 2022, according to a study by the firm Morgan Stanley; in their report, *The Rise of the E-Commerce Ecosystem 2022*, it estimated that by 2026, e-commerce will represent close to 20% of total retail sales in Latin America (AL). In the post-pandemic era, the digital transformation of SMEs is essential, allowing them to adapt to technological changes and market dynamics, increasing their speed of response to the demands of their customers, from the strategic level aligning their business objectives and their investments in technical capabilities [7–9].

On the other hand, we see large social movements demanding climate action and more significant economic equity. In AL, most people believe the environment should be prioritised, even if it generates job losses and an economic slowdown. In 2012, 53% of people said they were satisfied with environmental preservation efforts; this fell to 42% in 2021 [10]. The pandemic also accelerated these changes in the values of consumers who today demand products and services with a lower environmental impact, and their supply chains have social responsibility practices such as fair and well-paid employment [11]. They also seek products and services that do not negatively affect health and contribute to well-being, such as organic products that are low in sugar and salt [5].

Adapting to these fundamental market changes is especially difficult for SMEs as they need to catch up in their dual transformation process. This lag puts the economy and well-being of the region at risk since 99.5% of companies are considered micro and small, representing 60% of formal employment, according to OECD data in 2019. For SMEs, the challenges in successfully adopting digital technologies to increase competitiveness are enormous since they require specific and extraordinary resources and managerial capabilities [12]. Likewise, for the adoption of social responsibility measures such as climate action and labour equity and happiness management [13].

In the European Union, dual transformation has evolved into a public policy called Industry 5.0 [14]. Industry 5.0 seeks to reorient consumption towards more sustainable forms, promoting regenerative and circular value chains that optimise resources, minimise environmental impact, and foster equitable prosperity [15]. The essence of this policy lies in the harmonious integration of human and technological capabilities, fostering an environment where advanced technology and artificial intelligence complement human skills rather than replace them, thereby enhancing creativity and innovation.

It is also recognised in theoretical models such as the "Twin Transition," which focuses on converging the green and digital transitions [16]. This approach highlights the importance of leveraging the potential of digital technologies to promote sustainability. The Twin Transition emphasises how emerging technologies, such as the Internet of Things (IoT), Big Data, and artificial intelligence, can facilitate sustainable and resource-efficient practices [17]. These technologies are crucial in creating a greener economy by optimising industrial processes, reducing waste, and improving energy efficiency.

Both approaches, Industry 5.0 and the Twin Transition, represent a significant evolution in industrial policy. It is not just about adopting new technologies but integrating them to promote industrial development, prioritising human well-being and environmental sustainability [15]. This paradigm shift reflects a holistic vision where technological progress and social and environmental responsibility are intrinsically linked, thus ensuring a more sustainable and equitable future for all [18].

However, starting the transformation process for SMEs requires strategically prioritising actions, initiatives, and investments, so the question is where to start. Currently, no diagnostic tool provides SMEs in AL with a roadmap that allows them to focus their efforts, according to their readiness or maturity, to start the dual transformation processes. The literature has shown successful models for implementing digital transformation processes [19]. These models are mainly based on the experiences of large companies in developed countries, where the determinants of a successful digital transformation are indicated [20].

A self-diagnosis model for SMEs in Latin America cannot be found in the literature that allows them to identify their strengths and weaknesses before starting a *dual transformation* process. There is no simple tool that allows SMEs to identify an investment and action path for their companies' digital and sustainable transformation. These paths are fundamental for their competitiveness and survival in the medium and long term.

Studying dual transformation in Mexico is imperative, as there are no specific tools or a defined path based on diagnostic models adapted to the country's social and economic conditions. The particularities and challenges SMEs face in

Mexico, such as resource limitations, access to technology, and managerial capabilities, play an essential role in articulating effective transformation models for this region.

A contextualised approach that considers Mexican SMEs' unique limitations and opportunities is required to address these challenges. An adequate diagnostic model would allow these companies to identify their strengths and areas for improvement before embarking on dual transformation processes. It would optimise using their limited resources and increase their chances of long-term success.

Therefore, this research aimed to "identify the readiness level of companies in Tijuana, Mexico, to adopt a dual transformation process, that is, their capabilities to undertake both digital and sustainable transformations". Based on the literature on measuring companies' progress in these transformations [21], a model with four dimensions and 12 critical elements for each type of transformation is considered. A questionnaire is administered to small and medium-sized enterprises in Tijuana, Mexico, between 2022 and mid-2023. The methodology of this research was quantitative, and the analysis was carried out based on descriptive analysis, by measures of central tendency in the data, as well as correlation analysis between the dimensions that made up each type of transformation in companies. The results of the model application, in addition to the individual diagnoses of the companies, provided an assessment of the general readiness level of companies in the region to adopt dual transformation processes, which can be used in the design of public policies in this country.

The contributions of this research to the scientific community are multifaceted. Firstly, it addresses a significant gap in the literature by developing a contextualised diagnostic model tailored to SMEs' unique challenges and opportunities in Latin America, particularly in Mexico. By focusing on the digital and sustainable dual transformation process, this study provides a framework for understanding how these enterprises can effectively navigate the complex landscape of modern business transformations. The model's validation through empirical data from Tijuana SMEs offers robust insights into these companies' readiness and specific needs, which can inform both academic discourse and practical interventions.

Secondly, this research contributes to the broader discourse on Industry 4.0 and sustainability by highlighting the interconnected nature of digital and sustainable transformations. It emphasises the importance of a holistic approach integrating technological advancements with environmental and social responsibility. The findings serve as a basis for further studies in other regions and sectors, promoting a more comprehensive understanding of how SMEs can achieve competitive advantage and long-term viability in an era of rapid technological change and growing environmental concerns.

After contextualising the motivations guiding this research, the following sections detail the state of the art on digital transformation, sustainable transformation, and dual transformation, where the hypotheses that guided this research are presented, as well as the proposed theoretical model. The design of this diagnostic model is based on the corpus of literature available on the factors determining the successful adoption of such processes. Next, the methodology employed for capturing and analysing the empirical data of this research is detailed. The results are presented, and finally, conclusions are drawn based on the readiness levels for implementing dual transformation in the companies analysed. Based on these results, the implications for business practices are discussed, and future lines of research are proposed.

2 Dual transformation: a success tool for companies

The search for business competitiveness is understood as the ability to maintain a dominant position in the market through innovation, technological appropriation, and adaptation to changes in demand [22] or as the ability of a company to comply sustainably to satisfy customers and make profits [23], leads with the adoption of new operating models [9].

In this context, Dual Transformation (DT) is characterised by the convergence of two transformative processes in the operational models of companies that allow them to maintain their competitiveness and integration into global value chains [24]. These processes are Digital Transformation (DgT) and Sustainable Transformation (ST). DT is a strategic approach that enables companies to maintain their competitive edge while integrating themselves into global value chains [25].

The conceptualisation of DT derives from concepts such as Industry 5.0, a new industrial development model for the European Union that seeks greater resilience and, at the same time, establishes an economic model that accelerates the transition towards sustainable well-being [14]. This framework builds on the model of the fourth industrial revolution [1], which is an essentially technological paradigm focused on greater efficiency through digital connectivity and artificial intelligence, and which in its application is called Industry 4.0. However, more than the Industry 4.0 paradigm,

as it currently conceives, is needed in the context of the climate crisis and planetary emergency, and it needs to address deep social tensions.

Other conceptualisations about the dual transformative process include the Twin Transition: Green and Digital, which highlights the necessary use of the potential of digital technologies to promote sustainability and achieve carbon neutrality goals [16]. Sustainability and digitisation are essential for companies to meet in the current socio-economic environment due to the risks caused by traditional manufacturing practices and the standards imposed by stakeholders and governments [26].

Regarding the importance of dual transformation, it can be argued that Digital Transformation (DgT) involves the integration of digital technologies into all areas of a business, which fundamentally changes how it operates and delivers value to its customers [27]. One key aspect of DgT is its ability to increase operational efficiency through several means, including task automation, optimisation of workflows, and introduction of new technologies in various business model elements [28]. Additionally, DgT facilitates data-driven decision-making by collecting and analysing real-time data, among other advantages of digitisation.

On the other side of dual transformation lies Sustainable Transformation (ST), which focuses on creating long-term value for businesses and society by addressing environmental, social, and governance (ESG) issues [29]. ST plays a crucial role in establishing a positive brand reputation, which can significantly impact a company's relationship with customers, investors, and employees [30]. By implementing sustainable practices and demonstrating a commitment to corporate social responsibility, companies can build trust and credibility with their stakeholders and improve their overall market positioning [31].

Furthermore, TS is essential to ensure compliance with environmental and social regulations. Companies prioritising sustainability initiatives are often leaders in adopting best practices beyond regulatory compliance, setting higher standards for their industry competitors [32]. By investing in sustainable practices and technologies, companies can reduce waste and optimise resource utilisation, resulting in cost savings and greater efficiency [29, 30]. Additionally, TS initiatives can help companies attract the best talent, as an increasing number of job seekers prefer to work for socially responsible organisations [33].

3 Digital transformation in companies

Digital Transformation (DT) refers to using information technologies to enable operational processes, business models, and consumer experiences that generate value [34]. This transformation impacts the processes, activities, and functions of companies, and its benefits are multiple, as it can affect sales, productivity, profitability, stakeholder satisfaction, business growth, intrapreneurship and other aspects that represent benefits for organisational development [35].

DT enables new models of relationships between companies and users or consumers [3], which has allowed the consolidation of e-commerce, robotics, blockchain, cloud computing, IoT, big data, virtual and augmented reality, machine learning, and artificial intelligence; all are essential technologies that provide companies with competitive advantages through innovation.

In this regard, authors like Albukhitan [36] mention five significant benefits of Digital Transformation to companies. The first is related to productivity, which improves thanks to faster and more informed development processes. The second is related to time optimisation derived from automation. The third is improving quality, thanks to the precise measurement of parameters and machine learning tools to detect quality defects and predict problems. The fourth is cost reduction, which is possible thanks to data analysis of the entire supply chain and better inventory management. Finally, the fifth relates to product personalisation, a critical customer selection factor.

Since digitisation generates multiple benefits for companies, they must seek practices that allow them to transition from traditional business models to new models that integrate information technologies [36]. Therefore, this phenomenon has recently become attractive to researchers in economic-administrative areas, gaining ground in current research agendas [37].

For this reason, various researchers have undertaken to delve into digital transformation models, evaluating their causes and consequences. For example, Zhang et al. [38] empirically studied the relationship between DT and productive efficiency in Chinese companies. Their results revealed that this type of transformation promotes business production efficiency through cost reduction, improved productive efficiency, and innovation.

Specifically, in small and medium-sized enterprises, Priyono et al. [39] analysed how they faced the environmental changes generated by COVID-19, seeking business model transformation through digitisation. These authors found

that small and medium-sized enterprises (SMEs) adopt different degrees of digital transformation, which can be classified into three groups depending on specific company factors. Firstly, some SMEs with high digital maturity respond to challenges by accelerating their transition to digitised companies. Secondly, some SMEs face liquidity problems and low digital maturity, opting to digitise only the sales function. Finally, some SMEs need more digital literacy but strong social capital support.

Based on previous studies, as well as the environmental conditions faced by companies in Tijuana, Mexico, the following hypothesis develops:

H1. Tijuana's companies, in their different sizes, present low levels of capabilities for digital transformation.

4 Sustainable transformation in companies

The Brundtland Report of the United Nations (UN) World Commission on Environment and Development in 1987 defines sustainable development as meeting the needs of the present generations without compromising the ability of future generations to meet their own needs. However, it understands that sustainability must go beyond the environmental aspect, considering human well-being, ecological health, and their interactions [40, 41].

That is why 2015, within the framework of the United Nations 2030 Agenda, 17 objectives were established as strategic pillars related to sustainable development in economic, social, and environmental areas known as the Sustainable Development Goals (SDGs) [40, 42]. Therefore, it is now considered that to promote sustainable development in an organisation's strategy, a defined vision is required, as well as a mission designed and aligned with the SDGs [43].

Moreover, the Covid-19 pandemic has underscored the importance of integrating sustainability into business. The global health crisis has revealed the fragility of economic and social systems, highlighting the need for resilient companies to adapt to drastic and sudden changes. Organisations have been forced to reconsider their strategies, adopting practices that address environmental sustainability and the well-being of their employees and communities. In this context, sustainable transformation (ST) is crucial for ensuring business continuity and adaptation to future crises [44]. The integration of sustainable practices improves response capacity in emergencies and strengthens long-term competitive positioning, aligning with the SDGs and contributing to creating a more resilient and equitable future.

Consequently, analysts of Sustainable Transformation (ST) argue that for it to be achieved, there must be an intention to promote it as a business strategy involving all areas and levels of the organisation, thus allowing the generation of economic, social, and environmental value [45]. Thus, models have been articulated to understand better the process of adopting sustainability-oriented practices that allow the visualisation of the causes and consequences of ST implementation [46].

It is essential to mention that ST has been analysed mainly from a theoretical perspective, which lacks sufficient empirical evidence. However, Goni et al. [47] integrated the most representative models of sustainable practices to identify the most recurrent characteristics of this process, synthesising sustainable business models into nine main aspects: sustainability, information technology, circular economy, value chain, core values, value creation, organisational values, performance management, and stakeholder engagement.

In Tijuana, Mexico, companies need to integrate sustainability principles deeply into their corporate strategies. Often, sustainable practices are limited to isolated initiatives or corporate social responsibility programs that need to be aligned with a holistic vision of ST. The COVID-19 pandemic has exacerbated this situation, highlighting the vulnerability of companies that still need to adopt a comprehensive sustainability approach. The health crisis has demonstrated the need for business resilience, emphasising the importance of sustainability from an environmental, social and economic perspective.

Many companies in Tijuana have begun to recognise that adopting sustainable practices is not only a response to regulatory and market demands but also a strategy to ensure their long-term survival. However, they still need to overcome significant challenges, such as the lack of financial resources, the absence of a clear regulatory framework, and a deficit in training and awareness of their employees on the importance of sustainability. Additionally, companies must collaborate with the government and other stakeholders to create a favourable environment that facilitates the implementation of sustainable practices.

The environmental conditions in which companies in Tijuana operate allow for the development of the following hypothesis:

H2. Companies of various sizes in Tijuana exhibit low capabilities for sustainable transformation.

5 Elements of evaluation of dual transformation

Addressing these transformative processes simultaneously in a dual model is a recent phenomenon, so no literature presents adoption models for them. When we ask ourselves Where to start the DT? a measurement instrument of the level of readiness of companies is required, particularly a model required for small and medium-sized companies in developing economies. Based on the literature on each of these transformative processes individually, we find fundamentals that allow us to design a model to evaluate the level of readiness of companies for adopting these transformation processes.

Determinants of success in adopting DgT have been identified, from which digital maturity models based on multiple dimensions are derived, including elements related to strategy, leadership, market, operations, people and skills, culture, governance and technology [48]. Additionally, in the way of adopting DgT, it is necessary to align with the company's strategic objectives, leverage external knowledge, involve all managers and employees, and develop dynamic capabilities [20]. To measure the level of success of DgT, levels of maturity can qualify it as incipient, developing and mature for each of the critical dimensions, starting with the digital strategy, leadership, organisational culture, talent development, and resource allocation [49].

Transformation processes are complex because it is necessary to understand the level of readiness of companies that allows the successful adoption of the transformation and optimises the available resources. Such an evaluation should focus on the dimensions of "Systemic Management", "Maturity in Business Processes", "Corporate Culture", and "Use of Data" [50]. Additionally, to understand the priority areas in the execution of DgT, it is recommended that other vital factors be considered, such as a clear vision and strong leadership, people and processes, customer experience, and business model transformation and innovation [21].

The risks of a poor assessment of the level of readiness include insufficient maturity of business processes, lack of skills and technical knowledge, lack of a digital strategy consistent with the business vision, insufficient funding, and insufficient participation of the company's management [51]. If these risks are not considered, the DgT process could fail at a significant cost to companies.

The research intends to address digital transformation based on four main dimensions, each with three fundamental elements: the strategy, the culture, the organisation, and the technical capabilities of the companies. These exact dimensions were used to empirically assess the level of preparedness for sustainable transformation under this assumption:

H3. Digital transformation and sustainable transformation can be evaluated based on the dimensions of strategy, culture, organisation and technical capabilities of companies.

Including these dimensions in the study of digital transformation and sustainable transformation guides us in proposing the model in Fig. 1.

6 Methodology

The methodology for this study involved a quantitative approach to prove or refute the existence of correlations between the variables above. The research design was non-experimental, meaning the natural conditions in which the variables were presented were not modified; additionally, it was cross-sectional, as the data was collected at a single point in time.

6.1 Data collection

The general approach to the process, which involved the research design, included the phases of data collection from primary and secondary sources and subsequent analysis and interpretation. As the primary data collection technique, 148 surveys were administered using a structured questionnaire to obtain data for statistical analysis [52]. The questionnaire included both open and closed questions. In addition, articles on double transformation were reviewed to extract dimensions for analysing sustainable and digital transformation. These dimensions informed the questionnaire's development and the research's overall framework.

6.2 Data processing and analysis

The collected data were processed and analysed using various statistical techniques to ensure a thorough examination of the research questions. Qualitative data analysis was carried out by coding fragmented data in open questions.

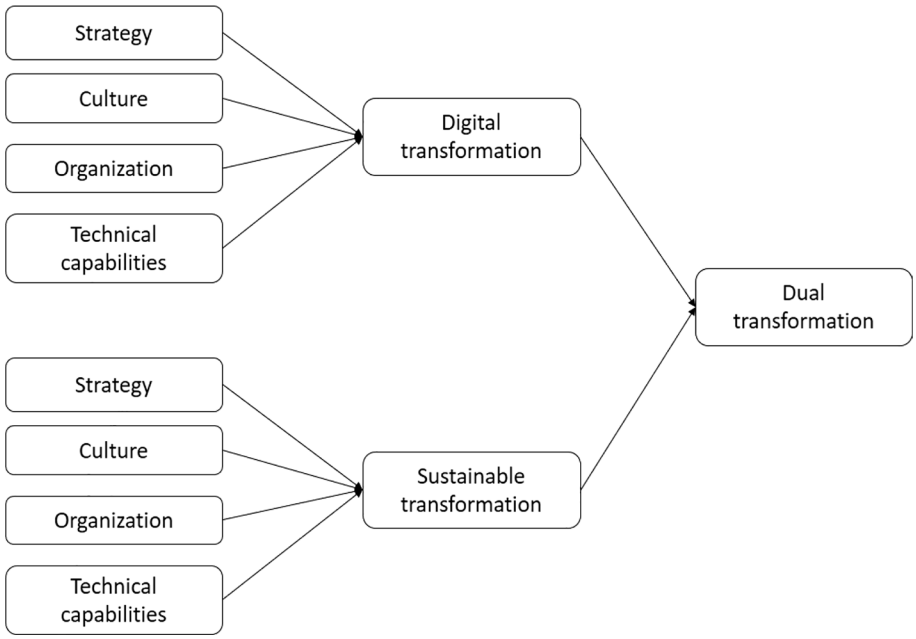

Fig. 1 Conceptual Dual Transformation Model. Source: Own elaboration

It uses Atlas Ti to identify underlying patterns and themes within the responses, aligning them with theoretical models. For quantitative data analysis, a descriptive analysis of the variables was initially performed using Excel, summarising the data to understand the essential characteristics of the data set. The instrument's reliability was then assessed using Cronbach's alpha in SPSS version 26 for Windows, measuring the internal consistency of the questionnaire and ensuring that the items within each scale reliably assessed the same construct. Finally, Pearson correlation coefficients were calculated to analyse the relationships between variables, a statistical technique that helped understand the strength and direction of the linear relationships between the variables.

6.3 Instrument

The survey used in this research was prepared based on the theoretical contributions of various authors [21, 48–50] and the UN Sustainable Development Goals [40], which try to answer from the perspective of *dual transformation*. We used questions about four categories, the first being related to the strategy in terms of communication, alignment and scope. The second is about culture related to change management, knowledge, and collaboration. The third organisation is in terms of leadership, processes, structure, and technical capabilities in data management, training, and integration of information systems for digital and sustainable transformation. Table 1 details the variables, dimensions, and elements that make up the determining factors that evaluate companies' level of preparation for adopting dual transformation.

The instrument was implemented as a self-diagnostic survey in an online form (Google Forms). Respondents were asked to indicate whether they agreed or disagreed with the statements described in Table 1, using a Likert scale where one meant "totally agree" and 5 meant "totally disagree." As a self-diagnostic instrument, the results demonstrate the companies' perception of themselves regarding their readiness for digital and sustainable transformation, together with dual transformation. The statements are formulated so that they represent an ideal state of readiness. The responses were classified according to the level of agreement with the statements in the following levels:

Low or Initial Level (Knowledge): Company is at a basic level of knowledge of the concepts, processes, benefits, and relationships with the company's competitiveness of Dual Transformation.

Intermediate Level (Commitment): TCompany is at an intermediate level of readiness for dual transformation once it has converted its knowledge into written implementation plans, goals, objectives, and scopes, which have been communicated to the organisation.

Table 1 Variables, dimensions, and elements for evaluating the level of preparation for the adoption of Dual Transformation

Variable	Dimension	Element	Objective	Question (affirmation)
Digital transformation	Strategy	Definition y communication	Assess the level of readiness in terms of the definition and communication of a digital strategy	The company has a clearly defined, programmed, and socialised (communicated) digital strategy
		Alignment	Assess the readiness level of companies in terms of the (vertical-horizontal) alignment of the digital strategy and the company's strategic objectives	The digital strategy is aligned with the company's strategic objectives
		Scope	Assess the readiness level of companies in terms of defining the scope of the digital strategy, whether it is only the scope of technological adoption, operational efficiency, or business model transformation, including customer experience, collaboration in the value network, innovation processes and decision making	The digital strategy has a scope of innovation and business model transformation beyond operational efficiency
	Culture	Change management	Assess the readiness level of companies in terms of their change management capacity and risk tolerance if they have policies and practices that encourage risk-taking and innovation, as well as processes to reduce resistance to change and the efficient adoption of new practices and technologies	The company culture encourages risk-taking and innovation, which facilitates the effective adoption of strategic changes
		Knowledge management	Assess the readiness level of companies in terms of their ability to manage knowledge, including documentation processes, process design, monitoring, and control of learning. E.g. use of Knowledge Management software	The company has the practices, processes and policies to manage knowledge effectively (intellectual property, systems, customer relationships)
		Collaboration	Assess the readiness level of companies in terms of their ability to foster collaboration in the organisation and facilitate communication and knowledge sharing. Application of collaborative processes and use of digital tools for collaboration	The organisational culture facilitates and promotes collaboration, communication, and teamwork
	Organisation	Leadership	Assess the readiness level of governance of the digital transformation process and how much trust the organisation has in its capabilities, knowledge, and leadership structure for the successful execution of the DT	The company's senior management has the commitment, knowledge, and governance necessary for digital transformation
		Processes	Assess the readiness level for digital transformation in terms of the design, documentation, and monitoring of operational processes aligned with the organisation's strategic objectives	The company has well-designed, clearly documented, and socialised (assimilated by the staff) operational processes
		Structure	Assess the readiness level of the company in terms of the definition of organisational structures that allow for internal and external collaboration in its value chain	The organisational structure is clearly defined (roles and responsibilities) and aligned with the processes, facilitating internal and external communication and collaboration

Table 1 (continued)

Variable	Dimension	Element	Objective	Question (affirmation)
	Technical Capabilities	Data management	Assess companies' readiness levels regarding their data management capabilities and information culture. Use of information systems for decision-making (ERP, CRM, business intelligence, cyber-security)	The company has a culture of decision-making based on data and has systems to access information promptly
		Training	Assess the readiness level of the company in terms of its processes, prioritisation, and investments in talent development, training, and technical training of its personnel	The company has the programs and the personnel training budget to assimilate new systems and fulfil its functions effectively
		Systems Integration	Assess the readiness level of the company in terms of its ability to integrate information systems from the various functional areas, business units, remote offices, customer relations (e-commerce), and suppliers (purchasing)	The company's information systems are effectively integrated, allowing access to data across departments and externally with suppliers and customers

Source: Own elaboration

Table 2 Profile of the companies surveyed

Category	Concept	Frequency	%
Sector	Services	85	57.4
	Wholesale	22	14.9
	Retail	18	12.2
	Industry/Mfg	23	15.5
Size (# employees)	Micro 0–20	49	33.1
	Small 21–50	36	24.3
	Medium 51–100	23	15.5
	Large 100 +	40	27.0

Source: Own elaboration

Table 3 Frequency table of companies that export, have offices outside the city, and have quality certifications

Category	Concept	Frequency	%
Export	Yes	42	28.4
	No	106	71.6
Foreign offices	Yes	86	58.1
	No	62	41.9
Quality certification	Yes	57	38.5
	No	91	61.5

Source: Own elaboration

Advanced Level (Resource Allocation): Company is at an advanced level of readiness when it has transitioned from plans to the allocation of financial, human, and knowledge resources necessary to implement the defined plans and objectives.

A sample of 148 surveys was conducted with business leaders in Tijuana, Mexico, and application techniques were used that consisted of communication technologies, specifically email. The surveys targeted professionals in various sectors, including manufacturing, services, wholesale, industry and technology. The positions covered ranged from managers and directors to owners of micro, small, medium and large companies.

7 Results

Initially, the analysis of data collected with the instrument consisted of organising a database and identifying the profile of the companies surveyed, which belong to different industries such as services, wholesale trade, retail trade and services. These data were analysed with descriptive statistics through measures of central tendency or frequencies. The results are shown in Table 2.

The frequency of the companies' business sector indicates that the majority belong to the services sector, consistent with the predominant business sectors in the city of Tijuana, according to the National Statistical Directory of Economic Units of the National Institute of Statistics.

In terms of the characteristics of the companies, their size is presented, measured by the number of employees. The information was therefore classified into four groups: micro (0–20 employees), small (21–50), medium (51–100) and large (more than 100 employees). The most frequent companies are micro-companies, followed by large companies. The size categories were taken based on the stratification of the Official Journal of the Federation.

Additionally, the companies were classified according to their operational characteristics: whether they export, whether they have off of Tijuana, and whether they have questions. The results are detailed in Table 3.

Then, the SPSS software version 26 for Windows was used to conduct the statistical analysis of the instrument used. It allowed us to perform reliability analyses and a correlation study between dimensions and the level of readiness for dual transformation in companies in Tijuana, Mexico.

Cronbach's Alpha evaluation technique was used for the reliability analysis of the scale. Table 4 shows the results of the analysis, which shows an internal consistency of 0.945 for digital transformation and 0.971 for sustainable transformation. It allowed us to determine that the items that indicate the constructs of the scale are reliable at a satisfactory level and that, at first glance, it can be presumed that there are correlations between them as they exceed the minimum acceptable value for this test [0.6] [53].

On the other hand, a correlation study was carried out using the same software (Tables 5, 6, and 7) to verify the significance between dimensions for dual transformation. The result of this study shows a correlation using the Pearson index, which is significant between the achievement of digital transformation and sustainable transformation.

The data represents a correlation matrix between four variables related to digital transformation. Each cell of the matrix shows the Pearson correlation between the corresponding variables. The values indicate that these correlations are significant at a confidence level of 99% (0.01). These values express the strength and direction of the linear relationship between the variables. In this case, stall variables appear to have strong positive correlations. One variable increases, and the other also tends to increase. The statistical significance suggests that these correlations are not the result of chance.

Additionally, the data indicates that all of the mentioned correlations are significant at the 0.01 level, which means that it is unlikely that these correlations are due to chance. In summary, the table provides information on how different dimensions related to digital transformation correlate, and all correlations are positive and significant. The correlations with the greatest strength are between DigOrg and DigCul, with a value of 0.843.

In Table 6, the data represents a correlation matrix between four variables related to sustainable transformation. In this case, there are strong positive correlations between all variables. The correlations with the greatest strength are between the variables SosOrg and SosCul, with a value of 0.901, indicating that as the sustainability culture increases, the organisational capacity for sustainability tends to increase.

In Table 7, the data represents correlation coefficients between different dimensions of *Dual Transformation*. In summary, all correlation coefficients are positive and significant, which suggests strong and statistically supported associations between the different dimensions of *Dual Transformation*. This analysis supports the idea that an increase in one

Table 4 Reliability analysis of the instrument

	Reliability
Transformation dual	0.973
Transformation digital	0.945
Transformation sustainable	0.971

Source: Created by authors, based on SPSS

Table 5 Correlation between digital transformation dimensions

Digital transformation				
	Digest	DigCul	DigOrg	DigCap
Digest	1			
DigCul	0.679**	1		
DigOrg	0.692**	0.843**	1	
DigCap	0.637**	0.809**	0.813**	1

**Correlation is significant at the 0.01 level (2-tailed)

Source: Own elaboration

Table 6 Correlation between Sustainable Transformation dimensions

Sustainable transformation				
	SosEst	SosCul	SosOrg	SosCap
SosEst	1			
SosCul	0.839**	1		
SosOrg	0.841**	0.901**	1	
SosCap	0.825**	0.839**	0.891**	1

Source: Own elaboration

**Correlation is significant at the 0.01 level (2-tailed)

Table 7 Correlations between dual transformation dimensions

Correlations between dual transformation dimensions								
	DigEst	DigCul	DigOrg	DigCap	SosEst	SosCul	SosOrg	SosCap
DigEst	1							
DigCul	0.679**	1						
DigOrg	0.692**	0.843**	1					
DigCap	0.637**	0.809**	0.813**	1				
SosEst	0.625**	0.747**	0.737**	0.771**	1			
SosCul	0.594**	0.697**	0.713**	0.700**	0.839**	1		
SosOrg	0.574**	0.662**	0.706**	0.674**	0.841**	0.901**	1	
SosCap	0.546**	0.628**	0.621**	0.674**	0.825**	0.839**	0.891**	1

Source: Own elaboration

**Correlation is significant at the 0.01 level (2-tailed)

dimension of sustainable transformation is related to an increase in the dimensions of digital transformation, which could indicate a positive interconnection in the context of *dual transformation*.

The overall mean for digital transformation in Tijuana companies is 2.36, indicating an intermediate level of readiness with a tendency towards advanced (Table 8). Thus, the lower mean value represents the highest level of readiness. The overall mean represents a combined measure of the following dimensions: DigEst, DigCul, DigOrg, and DigCap.

The overall mean for sustainable transformation is 2.62, indicating an intermediate level of readiness (Table 9). A lower score indicates a higher level of readiness for sustainable transformation. The overall mean represents a combined measure of the following dimensions: SosEst, SosCul, SosOrg, and SosCap.

In summary, companies in Tijuana perceive themselves as being at an intermediate level of readiness (Fig. 2) to adopt dual transformation. The variable with the highest level of readiness is "DigCul" (digital culture), with a mean of 2.24 in the digital transformation part. In contrast, the variable with the lowest level of readiness is "SosCap" (sustainability technical capabilities) in the sustainable transformation part, with a mean of (2.74). Generally, companies perceive themselves as being more prepared for digital transformation (mean 2.36) than sustainable transformation (2.62).

Figure 3 provides information on how the readiness levels in dual transformation vary according to the size of the company and the different dimensions analysed. In general, larger companies tend to have higher values in most dimensions, suggesting a higher level of readiness in dual transformation. Medium-sized companies perceive themselves to have the lowest readiness levels, followed by small and micro companies that perceive themselves with better readiness levels. Micro and small companies perceive themselves as having very similar intermediate levels of readiness; in some areas, small companies perceive themselves as having lower levels than micro companies. These patterns can provide valuable information for strategic decision-making and the development of dual transformation initiatives adapted to the company's specific size.

Table 8 Means by a dimension corresponding to digital transformation

Variable	Dimension	Media
Transformation Digital = 2.36	Digest	2.48
	DigCul	2.24
	DigOrg	2.30
	DigCap	2.43

Source: Own elaboration

Table 9 Means by a dimension corresponding to sustainable transformation

Variable	Dimension	Media
Transformation sustainable = 2.62	SosEst	2.61
	SosCul	2.57
	SosOrg	2.55
	SosCap	2.74

Source: Own elaboration

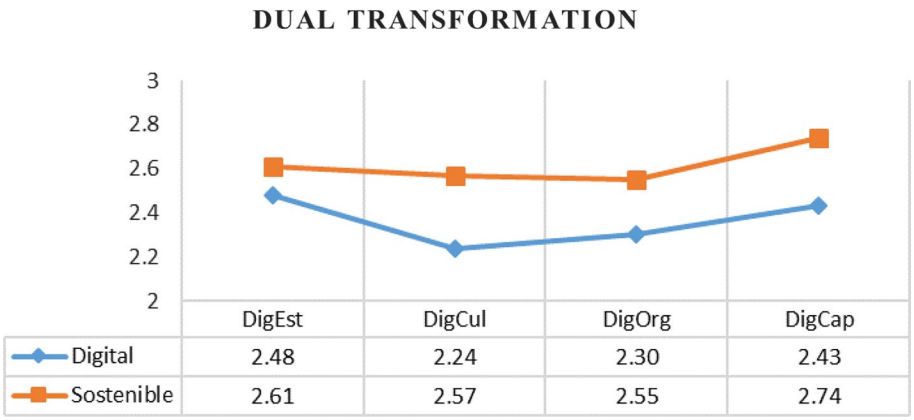

Fig. 2 It means corresponding to dual transformation. Source: Own elaboration

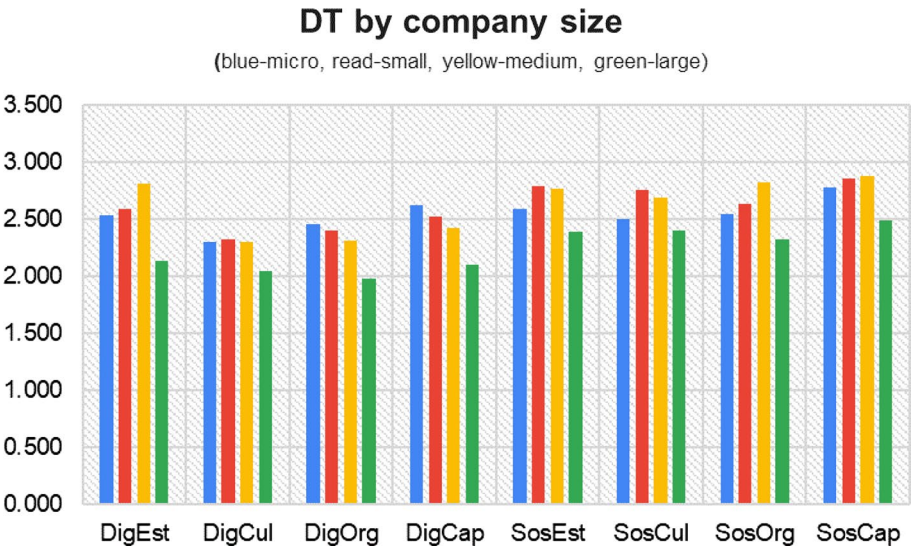

Fig. 3 Dual transformation by company size. Source: Own elaboration

8 Discussion and conclusions

The results of the self-diagnosis showed very high levels of correlation between the variables measured, which indicates that the dimensions and elements defined as determinants to measure the level of preparation of companies in terms of their ability to adopt digital and sustainable transformation processes are closely interrelated and, together, allow to determine the perception that companies have of themselves in terms of their level of preparation.

The research objective of identifying SMEs' readiness level in Tijuana was successfully met, as the responses align with the hypotheses formulated. The results reveal an intermediate level of preparedness, with notable variations based on company size, highlighting a significant lag among smaller enterprises. This finding is in line with prior research by Chandra et al. [12]. Interestingly, there are exceptions where micro-enterprises exhibit a more favourable perception of their preparedness levels than small and medium-sized enterprises, particularly in the strategic dimension, which falls under the purview of managers.

The statistical results show us high levels of correlation between the proposed dimensions, which coincides with the determining factors of success in the implementation of digital transformation processes, including elements related to strategy, leadership, market, operations, people and skills, culture, governance and technology, raised by other authors [48–50]. Additionally, we see a coincidence with the risks posed by Dolganova and Deeva [51], where a low level of preparation in the strategy dimension is reflected in a low level of preparation in technical capabilities, demonstrating the incongruity in investment and resource allocation.

Furthermore, as shown in Fig. 4, the data analysis corroborates the hypothesis (H1), positing low levels of digital transformation capacity among Tijuana's companies. Similarly, the hypothesis (H2) suggesting low levels of sustainable

transformation capacity in Tijuana has also been supported. These findings underscore the pressing need for targeted interventions and support mechanisms to bolster the digital and sustainable transformation efforts of SMEs in the region.

Companies with low capabilities for dual transformation represent a niche opportunity for implementing specialised training programs and developing support initiatives by government entities and private sector organisations. These efforts could improve technological infrastructure, promote sustainable business practices, and facilitate access to financial resources for innovation and business modernisation.

Moreover, a comprehensive approach is required that considers not only the adoption of digital technologies but also the integration of sustainability practices that contribute to long-term economic growth and business resilience in the face of future challenges. In this regard, collaboration among different actors within the business ecosystem, including academics, entrepreneurs, and government agencies, is essential to fostering an environment conducive to dual transformation and sustainable development of SMEs in Tijuana.

Organisations within the business ecosystem in Tijuana exhibit the general characteristics of companies in Latin America, where a large part belongs to the informal sector. It is particularly notable in the case of family businesses, which constitute an essential part of the business fabric in the city. In these family businesses, management and ownership are often closely linked to family dynamics, which often contributes to greater flexibility and adaptability to market changes.

The presence of the informal sector reflects both the opportunities and challenges businesses face in Tijuana. On the one hand, the flexibility of these companies allows for relatively easy changes in the business model when oriented towards implementing better environmental or technological practices. On the other hand, informal conditions prevent them from accessing state resources, leave them vulnerable to closure or fines due to lack of legal protection, and deprive employees of social benefits, contributing to higher turnover rates than other regions and hindering talent retention and sustainable growth.

Regarding the importance of implementing digital transformation initiatives in companies, theorists argue that digitisation changes how SMEs create and deliver value, for example, how they interact with customers, deliver their products or services, and integrate IT into the company's core operations [54, 55]. An extensive list of opportunities for implementing technological innovations can be seen as incentives for digital transformation, which could mainly benefit small and medium-sized enterprises, particularly in improving their competitive capabilities [56].

On the other hand, concerning the importance of implementing sustainable transformation initiatives in companies, the academic literature argues that socially responsible companies generate higher levels of consumer trust, leading to better brand perception among customers and a sense of belonging and commitment among employees [57]. Therefore, sustainable transformation should be more than just a strategy implemented by large companies.

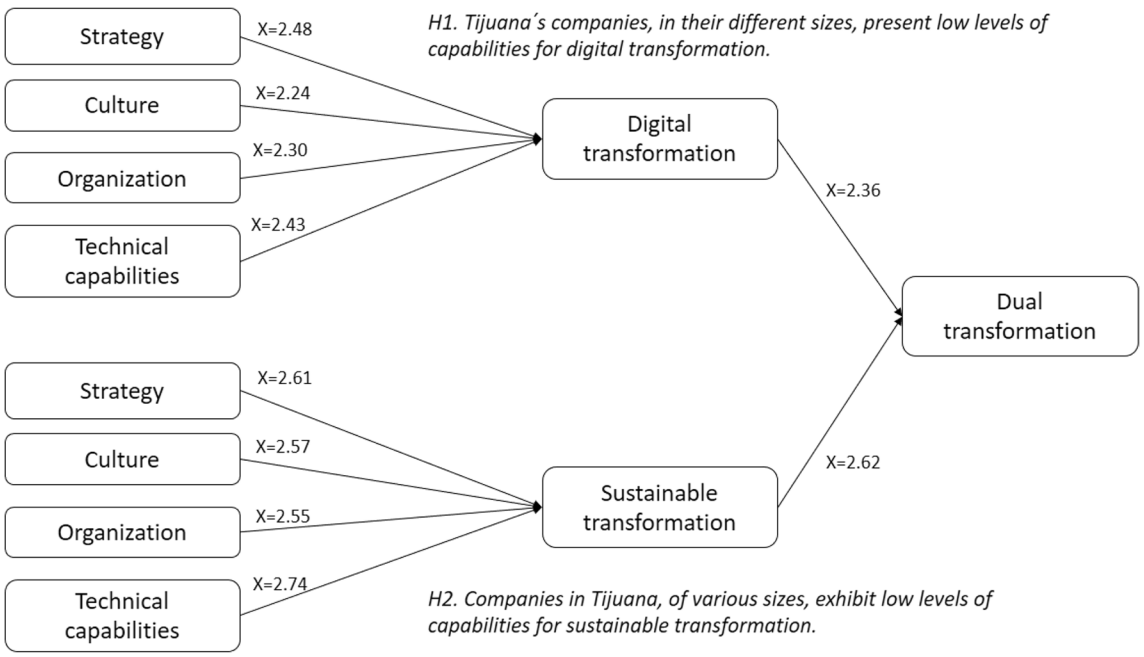

Fig. 4 Results of model. Source: Own elaboration

Regarding small and medium-sized enterprises, Das et al. [58] argue that social and environmental sustainability practices are grossly neglected in SMEs, specifically in emerging markets. It is mainly due to ignorance of the impact of businesses on ecosystems or social development, lack of adequate support and training, shortcomings in public policies for environmental and labour protection, minimal labour standards requirements, and the lack of oversight by authorities on issues concerning SMEs in emerging economies [58].

The results are categorised into three levels of preparation, the lowest being those results with averages between four and five, the intermediate level being the value of the average of three, and the highest levels of preparation being those averages between zero and two. It allows us to make the following judgments about how companies perceive themselves in terms of their levels of preparation and according to their size:

8.1 Large companies

Comparatively, these companies have a more favourable opinion of themselves in terms of their level of readiness. They perceive themselves with higher readiness levels in digital transformation than sustainable transformation. In both cases, the dimension where they perceive a more significant weakness is technical capabilities, compared to the organisation dimension, where they perceive themselves to have higher readiness levels. This perception may reflect that although there is a firm commitment from senior management and well-defined operating processes, sufficient investments still need to be made to increase the technical capacity of the personnel or the necessary information systems.

Large companies generally have adequate structures that allow them to support transformation initiatives [59], although it is necessary to recognise that there are challenges related to the implementation of advanced technologies and the training of their staff in using these technologies [60]. This mismatch suggests a need for strategies focused on developing specific technical skills and updating technological infrastructures [61]. Furthermore, it is recognised that sustainability is and will continue to be an area of development for large companies [62]. It could be due to the complexity of integrating sustainable practices across all operational areas and the need for a cultural change that promotes sustainability as a core company value.

8.2 Medium-sized companies

These companies have the lowest level of perception of themselves regarding their readiness to adopt the dual transformation process, even lower than micro-companies. The company culture is the dimension in which they perceive themselves most positively. Their most negative perception varies in each type of transformation; in the digital one, it is the strategic dimension, and in the sustainable one, it is the technical capabilities. This perception may stem from the fact that the managers of these companies are sufficiently aware of the challenges involved in the transformation process and still need the resources to achieve it successfully.

In digital transformation, medium-sized companies need a clear strategy and long-term plans, which prevents them from taking full advantage of new technologies. In contrast, the main barrier to sustainable transformation is the need for more technical capabilities and trained personnel, aggravated by a lack of access to financing [63, 64]. To improve, these companies must develop a coherent strategy integrating transformations and investing in technical training. Collaboration with educational institutions and searching for financial support are vital to advancing its dual transformation process.

8.3 Micro and small companies

Small companies show a very similar perception to medium and large companies, at consistent intermediate levels in all dimensions; however, their most favourable levels are in terms of company culture and the least in terms of technical capabilities. Having few employees gives these companies more control over values, communication, and collaboration. However, they need the human or technical resources to feel confident in their technical capabilities.

Among the main advantages small businesses present for digital transformation is agility in decision-making, which allows them to quickly adapt to changes and opportunities in the environment [65]. Likewise, the leaders of these companies have more excellent proximity to customers, which allows them to timely perceive their needs and adapt their transformation processes to the demands of their market; therefore, an excellent dual transformation strategy in these companies would consider concrete sustainability and digitalisation actions, adapted to the basic needs of its clients.

9 Practical implications

Based on the previous analysis, it is imperative to issue some recommendations that allow the theoretical contributions to be placed in a practical dimension. In general, the dimension where they perceive their lowest level of preparation is in terms of technical capabilities. A more significant investment in training, adequate information systems, and efficient data use is required to improve in this area. Improving technical capabilities must be a priority, especially in sustainable transformation.

Additionally, strategic alignment is crucial. In digital and sustainable transformation, the perception is very similar, with a lower standard deviation of the means. There needs to be more alignment with the business's strategic objectives and the scope of the transformation processes. Therefore, aligning with the business model from a shared value perspective is necessary, integrating the transformation into the company's competitive differentiators.

Based on this information, it is imperative to recommend that business leaders in emerging economies invest in training programs for personnel, especially in aspects related to the development of IT competencies or sustainability practices; implement adequate information systems; seek opportunities to leverage technologies based on best innovation practices from developed countries; integrate dual transformation into their business models, ensuring that these changes are consistent with strategic objectives; create a shared vision towards digital and sustainable transformation; manage change so that all personnel commit to the new strategic directives; foster a culture of innovation and corporate social responsibility; create support networks with the business or academic sector to share best management practices in dual transformation; and collaborate with the government in developing digitalisation and business sustainability practices.

10 Future lines of research

It is recommended to continue with qualitative research where successful cases and their best practices in the transformation process are identified. This research could be carried out with in-depth interviews, following the structure of the dimensions and elements proposed to evaluate the level of preparation.

It is also recommended that aspects related to digital transformation and the adoption and transfer of knowledge in companies be investigated. The above is faithful in that, in most companies, staff training was presented as one of the main limitations in implementing digital transformation. Likewise, the impact of the dual transformation will be analysed based on longitudinal quantitative models that indicate the results of the company's performance before and after the implementation of digital and sustainable transformations.

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Data availability The survey data are retained by the authors and they are willing to provide them, if necessary, for validation of the information.

Declarations

Competing interests The authors declare no competing interests.

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