A Digital Transformation Index for Business Organizations: Reckoning the Extraverted Change in Pillars

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Abstract

Digital transformation (DT) is an emergent concept with definitions and measurements as a work in progress. During nearly two decades of growing interest in the concept, studies in both industry and academia created different scales and indices to measure DT, using varying conceptualizations and coming up with different underlying dimensions and indicators. The aim of this paper is to take stock of this growing body of work through a systematic review in order to first determine dimensions and indicators of an encompassing DT index, and then identify the contemporary change in underlying dimensions of DT. After reviewing 164 research articles on DT measurement in the first phase, we have identified 80 indicators falling under 14 different dimensions. In the second phase, we have compared our results with scales commonly used in the field and identified several emergent dimensions, such as cyber security, investment and finance operations, and partnerships. Emergence of these contemporary dimensions indicate an 'extrovert' shift in DT concept which is extending beyond organizational boundaries, with important implications regarding how businesses strategize and take action in today's DT driven business environment.

Keywords: digital transformation, formative index development, business organizations, Industry 4.0

1. Introduction

Digital transformation (DT) has emerged from its original cocoon of large-scale manufacturing firms in developed countries, reaching the forefront of strategy for many organizations beyond that niche. While it is becoming an important driver of competitive advantage(Drath and Horch, 2014; Leão and Da Silva, 2021) it is an evolving phenomena and its"impacts on firms' competitiveness present a complex and wide range of results" (Leão and Da Silva, 2021).

With DTs emergent prominence in competitiveness, DT measurement is becoming vital as its assessment becomes an important pillar of strategy (Kontić and Vidicki, 2018). However, definition and measurement of this evolving phenomena remain a work in progress. Major global consultancy firms and government-supported initiatives to model and measure DT each have had their own interpretations, resulting in a variety of measurement schemes to assess the digital transformation process of organizations, especially of manufacturing firms. A brief glance at the research and practice around DT measurement highlights a void of consensus regarding its 'dimensions' (Schumacher et al., 2016), a term commonly used in the related literature for referring to bundles of DT indicators. For the most part, these attempts are based on a priori categories of organizational qualities taken from broader management experience, such as organizational, strategic, process or supply chain management related factors, in addition to technological factors. Consequently, a growing body of research focuses on DT measurement, including valuable reviews which attempt to consolidate the experiences in this literature (e.g. Vial, 2019) and empirical studies aiming to identify a suitable set of DT dimensions and metrics (e.g. Mergel et al., 2019).

Our study aims to contribute to a better understanding of DT for business organizations by uncovering the changes in its understanding in the field. To this end we follow a two stage research design. In the first stage, we take stock of the DT measurement literature and, applying an appropriate angle in DT measurement scale development, we develop a contemporary DT index. Following this, in the second stage, we identify the changing pillars of DT by contrasting this newly developed index with earlier ones commonly employed in the field practice. The paper explores how the changes we identified with this process holistically highlight a broad turn in DT which extends from its originally intra-organizational focus to an extroverted one that involves cross-boundary processes and technologies reaching out to external stakeholders, introducing a whole new range of issues for theory and practice of DT.

Underlying our first stage is a distinction between reflective and formative scale development (Diamantopoulos and Winklhofer, 2001; Jarvis et al., 2003). This distinction concerns the nature of the phenomenon which is the subject of any measurement. In some cases, there is a latent entity to be measured, which requires a 'reflective' methodology to measure its manifestations using appropriate indicators. Such an approach is appropriate, for example, in the case of measuring customer satisfaction or organizational culture, where the underlying construct 'exists' in a person's mind, or in the beliefs of the organization's members, and it is reflected in indicators measured using survey questions. In other cases, however, the targeted construct is not an independent entity, but it is a 'formed' from indicators, rather than being reflected by them; i.e. it is defined by the indicators rather than underlying them. This is the case, for example, when measuring an individual's socio-economic status 'formed' from indicators such as income, neighborhood, and residence. While developing measurements in the social sciences, the distinction between reflective and formative scales is often overlooked (Diamantopoulos and Winklhofer, 2001; Jarvis et

al., 2003). In most organizational studies, researchers assume the former, reflective methodology even when inappropriate, resulting in major flaws in scale development due to very different developmental and analytical procedures behind each of the two assumptions (Diamantopoulos and Siguaw, 2006). Here we subscribe to the conviction that measurement of DT is a case of the latter type. Conceptually digital transformation of a business organization is not an inherent construct, unlike, for example, organizational culture. Within this perspective, our study attempts to deliver a formative index for digital transformation of business organizations. We achieve this via a systematic literature review to find the 'contemporary' set of indicators underlying DT and then applying analytical procedures for scale validation according to formative index development methodology.

On the other hand, any effort to establish a DT measurement scale should be considered in vain, and that the resulting scale is transient. This is because DT is an evolving concept and does not have 'natural' constituents that can be discovered, nor dimensions that can classify these constituents. As the practitioner's interest and experiences with DT continue to spread into new realms, its constituents will keep evolving, eroding the validity of existing scales. Thus, the nature of DT measurement entails a rolling, rather than a fixed definition of DT, at least for the foreseeable future. Consequently, our second and ultimate aim in this study is to consider these developments and chart the changes during the last decade, by comparing constituents in our contemporary scale with those from the past common practice.

In the following section we first review the literature to identify variations in DT measurement experiences and scale development methodologies. The third section explains our research design and methodology for the two stages: developing a formative index and then identifying the shifts in DT. Section four summarizes our findings on emergent dimensions of DT, followed by a section discussing the implications of our findings, and a concluding section on limitations of the study and future research directions.

2. Theoretical Backdrop: What constitutes Digital Transformation and how to find it?

Despite the growing interest in DT, its definition and consequently its measurement is considered a work in progress, and intermingled with other concepts (Vial, 2019; Gong and Ribière, 2021; Hanelt et al., 2020). The concept of DT is often used ambiguously and interchangeably with concepts such as digitization, digitalization, and Industry 4.0 (Hermann et al., 2016; Rojko, 2017; Gadre and Deoskar, 2020; Leão and Da Silva, 2021). On a general level, Industry 4.0 is considered as a 'desirable state of industrial firms' based on technologies, characteristics, and outcomes (Culot et al., 2020), whereas DT is a broader process leading to such end states regardless of the type of organizations. Business value creation and use of technology are often emphasized as two of its

defining features (Mergel et al., 2019; Morakanyane et al., 2017; Osmundsen et al., 2018; Gong and Ribière, 2021). To avoid conceptual ambiguity, we adopt a simplified cross between Morakanyane et al. (2017) and Gong and Ribière (2021), and hereupon define DT as "an organizational change process that leverages digital technologies to create value".

As the interest in DT has grown in recent decades, there have been various attempts to define and measure it. These attempts to disambiguate the concept have employed multiple dimensions and concrete indicators to develop scales for measuring and monitoring DT. Some of these are motivated by scientific interest in a more substantial understanding of DT, whereas others are practice led, aiming to provide tools for monitoring and managing DT at the business organization level. Our study is also confined to measurement of DT at the business organization level. Furthermore, we subscribe to the notion that each of these attempts to disambiguate DT is a piece of the puzzle, which holistically reflects our collective understanding of DT. The wide range of dimensions and indicators in this evolving collective effort prompts a need to take stock and reflect upon the changing nature of our collective understanding of DT.

The first subsection below summarizes measurements from both industry and the academic literature to lay out commonalities, differences, and shortcomings. The second subsection presents an overview of measurement methodologies, with the aim of identifying the appropriate methodology for measuring the DT phenomenon.

2.1. DT measurement landscape

Many measurement models to assess digital transformation were developed in the previous decade (Lichtblau et al., 2015; Geissbauer et al., 2016; Pacchini et al., 2019; Schumacher et al., 2016; Berghaus and Bäck, 2016; Nwankpa and Roumani, 2016). These works evolved against the background of an emergent topic, resulting in limited convergence in their disambiguation (Pacchini et al., 2019; Schumacher et al., 2016). Nevertheless, these models, mostly from the last decade, became popular among practitioners and contributed considerably to navigating an important and emerging phenomena by businesses, but each with their own take on the question of 'what constitutes DT?'. The diverse range of dimensions used in those models to answer that question include companies' digital transformation strategy, organizational structure and culture, technology (information technologies, production systems), employees, leadership, products, customers and customer experiences, and transactions; with each dimension further broken down into concrete indicators to measure it. As the field practice increasingly demanded assessment tools for digital transformation, it is not surprising that multiple models and corresponding tools have been introduced in a relatively short period.

These models, originating from either industry or academia, vary in their use of terminology, scope, dimensions, and indicators for measurement. For example, the IMPULS Readiness Model (Lichtblau et al., 2015), a government and industry joint effort

from Germany, focused more on manufacturing processes with limited emphasis on organizational factors, whereas the PricewaterhouseCoopers (PwC) Maturity Model (Geissbauer et al., 2016), from a prominent consultancy firm, emphasizes digital business models, customer issues and such, with relatively less emphasis on manufacturing processes. Similar to this example comparison, significant variety is visible across these DT models popular among practitioners. Considering the fact that these models are targeting the same segment of -manufacturing industry- businesses, such differences firstly highlight a business DT landscape in which practitioners face a choice of DT measurement models and tools each of which is rooted in a significantly different answer to the question of 'what constitutes DT?'. This landscape firstly indicates a lack of common understanding of DT. Secondly, as DT is not a 'natural' phenomenon but rather our -supposedly shared- conceptualization, the concept itself keeps evolving and thus prompts as assessment of what has changed over a decade after proliferation of those first generation of DT measurement models.

2.2. Differences in measurement methods

The first issue above highlights differences in how we approach the question of what constitutes DT? Most DT measurement attempts seem to be indifferent to methodological consequences of how they conceptualize DT, making a practice-driven distinction between "readiness" versus "maturity", a distinction which is often sluggish and fails to extend to measurement methodologies. Berghaus and Bäck (2016)'s study, for example, focuses on maturity, whereas the dimensions they use include, among others, various factors such as organizational agility, culture, and management support that underlie digital transformation rather than being its outcome. These dimensions are little different from, for example, an Industry 4.0 "readiness" scale developed at the University of Warwick (Agca et al., 2015), or tools developed by private sector groups, such as Gill et al.'s Digital Maturity Model (Gill et al., 2016). A government driven example for measuring Industry 4.0 (IMPULS) is an example noted for its consistency in its focus on material manifestations of firm digitalization, apart from being labeled as a "readiness" model rather than a maturity model. Some of these modeling attempts are positioned as tools for assessment of DT readiness, others for DT maturity, while yet others avoid the distinction. Readiness indicates the enterprise's level of preparedness for the development process, and maturity, its level of progress in this process; however, it has been observed that they are sometimes used interchangeably in the studies in the literature.

Apart from confusion over the labels of readiness and maturity, there is a deeper methodological issue here. The scale development literature calls for a distinction between two types of scales, each corresponding to different conceptualizations of the construct measured, and each requiring different statistical procedures (Jarvis et al., 2003). In cases where measures are dependent on latent constructs, reflexive scale methods are needed. This type of research design is so widely presumed that most

researchers adopt this approach, even when inappropriate (Jarvis et al., 2003). In other cases, the construct does not exist independently, but rather, is defined by the measures, i.e., it is an index, and this calls for formative methods. There are attempts in the literature to clarify the conditions for deciding the direction of causality (e.g. Edwards and Bagozzi, 2000).

An example of a proper reflective scale design is Crosby and Stephens (1987). Their marketing research aims to measure customer satisfaction resulting from the sales force's relationship management efforts. In such an example, the assumed direction of causality is from the latent core constructs to measures, as shown in Figure 1. There may be constructs in the middle (C1-through-C3 in the figure) which are different dimensions of a core, or thematic constructs. Regardless, each construct is measured with one or more measurable indicators (M1-through-M4 in the figure).

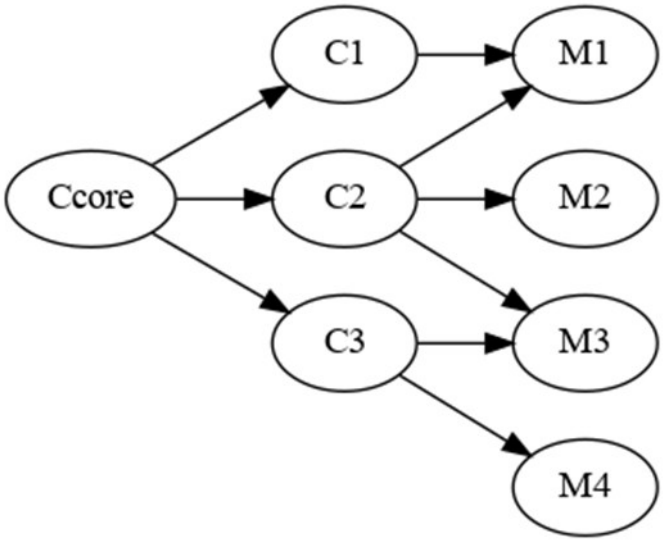


Figure 1: Causality direction in reflective scales

In contrast, defining a construct such as socio-economic status depends on the use of certain indicators (Hauser and Goldberger, 1971). Similarly, the human development index does not exist as a 'natural' entity, but is defined as a composite outcome of health, education, and income (Coltman et al., 2008). In these cases, the direction of causality is reversed, as depicted in Figure 2, in which measurements are collected under several constructs, which in turn, underlie an overall construct of interest. Such formative constructs are often called indices (Diamantopoulos et al., 2008).

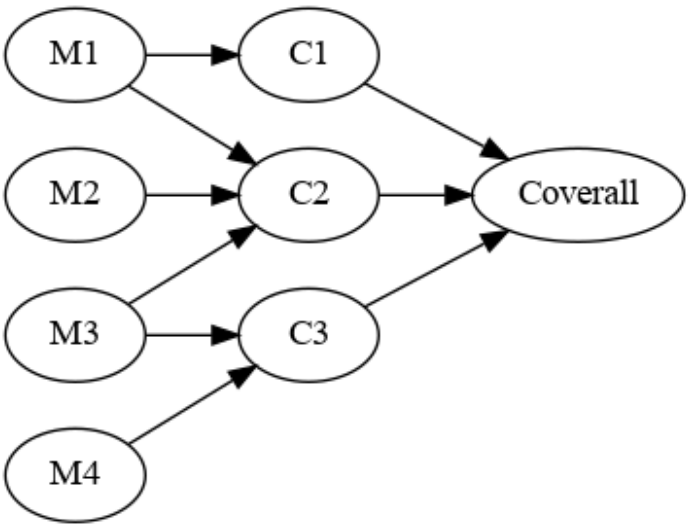


Figure 2: Causality direction in formative scales

Compared with these examples, we contend that DT is a formative construct. It is not a concept which has an independent existence inside the firm (in the way that customer satisfaction does in a customer), and which can be measured from its manifestations. Instead, it is a concept we are attempting to define through its constituting elements (such as social status or human development index in other examples). These two different construct types require different measurement scale design and rely on different statistical procedures for validation (Coltman et al., 2008; Diamantopoulos and Winklhofer, 2001).

Reviewing the DT measurement models in the previous section, we see rather limited discussion on measurement methodology. Berghaus and Bäck's (2016), Digital Maturity Model, for example, is implicitly, not explicitly, understood to apply a formative measurement approach. In contrast, the implicit assumption in most of the other the DT measurement models are of a reflective kind. It is important that digital transformation should not be measured reflectively. First, DT lacks a clear and unambiguous definition. Distinct indicators define DT characteristics, and a change in these would cause changes in DT construct, rather than the other way around. In fact, it is the concrete indicators used to substantiate DT which defines the concept. That means these indicators are not interchangeable, and if any of these increase, DT would increase; however, an increase in DT would not cause an increase in all indicators. Therefore, all related indicators used to define DT need to be comprehensively identified in order to delineate the construct's conceptual domain (Jarvis et al., 2003). For this reason, the indicators and sub-constructs must be systematically determined and must be complete. Unlike reflective measurement, where a limited number of indicators that reflect an underlying construct may be sufficient, a formative construct is only complete when all underlying indicators are determined systematically (Diamantopoulos and Winklhofer, 2001). Berghaus and Bäck's (2016), Digital Maturity

Model, for example, is also problematic in this regard, since its indicator survey, while seemingly impressive and complete, is in fact an ad hoc combination of findings from several methods.

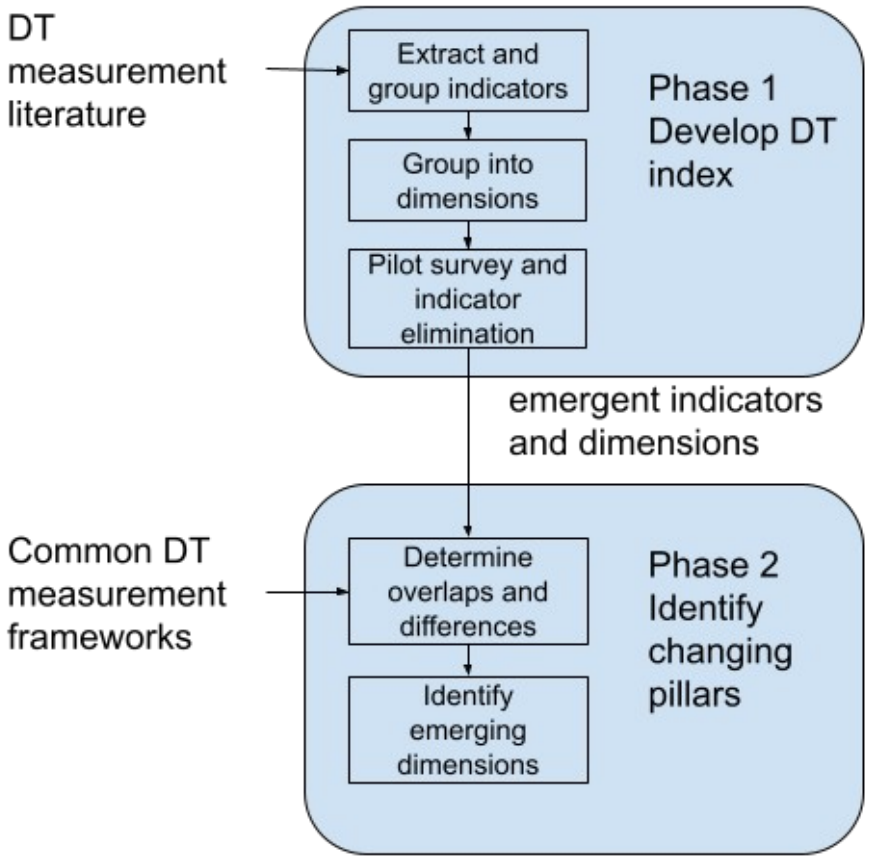
A sound measurement approach would enable one to approach the second research aim mentioned above: if one is able to capture the contemporary common understanding of DT in a formative index, it would be possible to chart the changes in our understanding of DT by comparing it to measurement models from the past.

3. Research Methodology and Data

Our research goal leads to a two phase research design, whose first phase is a systematic review to identify DT indicators and dimensions and second phase is identifying emergent dimensions by comparison to widely used DT measurement frameworks.

In the first phase DT is taken as a formative construct in our approach, and the underpinning indicators to measure it are determined by a comprehensive systematic literature review (Diamantopoulos and Winklhofer, 2001; Jarvis et al., 2003). This is followed by identifying main dimensions underlying these indicators. The last step of this phase is a pilot study and statistical tests to identify and eliminate repetitive indicators (Diamantopoulos et al., 2008). These steps in the first phase are depicted in the upper part of Figure 3 and detailed in section 3.1 below.

Following the first phase we return to comparing its results to DT measurement frameworks commonly employed in the practice to identify changing pillars of DT. The procedure for doing so is depicted in the lower part of Figure 3 and described in section



3.2 further below.

Figure 3: Overview of research design

3.1. Systematic review and index development

Following the systematic literature review methodology from Tranfield et al. (2003b) we have first selected the relevant literature from Web of Science (WoS). After several rounds of scoping we have ended up with a corpus of 164 journal articles published between 2003 and 2021 (most of them after 2018), that focus on measuring some aspect of digital transformation or Industry 4.0 in business organizations. With the selected works, we conducted a systematic reading to determine the measurement indicators used in these studies. A total of 1656 first order indicators identified in the whole corpus are later generalized through second and third order groupings to reduce the number of indicators down to 85 while keeping their coverage of the phenomena. An extract of this coding procedure is given in columns 1-through-3 of Table 1.

In the second step of this phase two researchers reviewed the indicators list and collectively created a list of 14 dimensions under which these indicators may be grouped into. Then, they independently classified the indicators to these dimensions, as exemplified in the last column of Table 1. To ensure reliability, inter-rater agreement (IRA) was measured and a value of 95% indicated an acceptable reliability of the classification process. The differences were resolved through discussion and mutual agreement. Later, the indicators were transformed into phrases to facilitate their use in a survey.

Table 1: A sample extract from DT indicators coding and grouping under dimensions

First order indicator and source in the literature	Second order group	Third order group	Final dimension & survey phrase
* Using RFID scanners that would bring the products to life on a screen (Hansen and Kien, 2015) * RFID & RTLS are used for Data Acquisition (Saad et al., 2021)	Using RFID technology	Technological resources	Dim.13 Technological resources, Q17: "Traceability technologies are available"
Availability of investments – to boost ICT (information and communication technologies) infrastructure (Roy and Upadhyay, 2017)	Having adequate financial resources for digitalization	Financial resources	Dim.12 Strategy, Q7: "Company provides investment and financial support for digitalization"

In the third and last step of this phase we have conducted a pilot study using the survey created, and collected 29 responses from a convenience sample of businesses in our region. This step is necessary to check the index for indicator collinearity and external validity (Diamantopoulos and Winklhofer, 2001; Diamantopoulos et al., 2008). Measurement methodologies rely on variance inflation factor (VIF) to determine any collinearity and eliminate some indicators. A VIF cut-off value of VIF>10 is recommended for this purpose (Diamantopoulos et al., 2008). When collinearity is detected, the two indicators should be merged. In addition to indicator refinement, the index needs to be reviewed for external validity. Thus, the pilot survey included two reflective constructs that measure consequences of digital transformation: Innovation and firm performance; both of which are positively affected by digital transformation (Nwankpa and Roumani, 2016). The inclusion of such reflexive constructs in the pilot survey made it possible to assess external validity of the refined index by using multiple

indicators and multiple causes (MIMIC) model (Hauser and Goldberger, 1971; Jöreskog and Goldberger, 1975; Diamantopulos and Winklhofer, 2001). The MIMIC model is fitted using both formative and reflective indicators, and goodness of fit is measured using root mean square error of approximation (RMSEA) to assess external validity of the model.

3.2. Identifying the changing pillars

As the field practice increasingly demanded assessment tools for digital transformation, multiple measurement scales have been introduced in the last decades. These models, originating from either industry or academia, vary in their use of terminology, scope, dimensions, and indicators for measurement. There is no registry of such scales, to our best knowledge. Therefore, we rely on our field knowledge to select a sample of DT scales that represent the common conceptualization in the field. We based our selection on the following criteria: (1) each scale provides a clear set of dimensions, (2) each scale was specifically intended for measuring DT in business organizations, (3) each scale targets a variety of industries and firm sizes, and (4) there is variety in terms of industry and academia originated scales in the sample. We include well-known ones of industry and consultancy origin, along with a smaller number of highly-cited ones from the academic literature. With this approach we have settled on six DT measurement scales, often called 'models', for our review in this phase:

1. IMPULS Readiness Model (Lichtblau et al., 2015): This model has its origins in industry and was approved by the German Engineering Federation. It targets larger businesses rather than small and medium enterprises (SMEs).
2. PricewaterhouseCoopers (PwC) Maturity Model (Geissbauer et al., 2016): This is another industry origin model from a prominent consultancy firm. It mainly focuses on digitalization strategies. Although it aims to cover all sectors and firm sizes, it is generally less suitable for SMEs.
3. Industry 4.0 Maturity Model (Schumacher et al., 2016): This model is from academia and targets enterprises engaged in production. The model was developed to measure the readiness level specifically of SMEs for Industry 4.0 technologies (Mittal et al., 2018).
4. SPICE-based Industry 4.0-Maturity Model (Gökalp et al., 2017): This model of academic origin is based on the SPICE (Software Process Improvement and Capability Determination) model to create an Industry 4.0 maturity scale. It is considered to be suitable for firms of different sizes.
5. Industry 4.0 Maturity Model (Akdil et al., 2017): It is an Industry 4.0 preparation model from academia. Its empirical focus is medium size manufacturing firms.

6. Digital maturity model (Berghaus and Bäck, 2016): This one is from industry, based on field research in Switzerland and Germany. This is the only one of the six which adopts a methodology in line with formative index development.

The above sample of DT measurement scales is neither extensive nor exhaustive, but to our best knowledge, it is representative of the DT assessment spectrum. We have additionally come across several national or regional DT measurement scales, whose developments are usually supported by national public agencies, such as Indonesian INDI 4.0 (Fernando et al., 2022) and Singapore's SIRI (Singapore Economic Development Board, 2018). However, these are excluded from our review, being reported to have similar dimensions and results with IMPULS Readiness Model (Musyarofah et al., 2022) above. Among many DT scales of academic origins, we have included only the most well-known and highly cited. There are also several other scales from consultancy firms or university-industry-government collaborations (e.g. Agca et al., 2015; Gill et al., 2016) which have similar European or North American origins, and whose dimensions overlap to varying extents with, for example, the PwC model in our list. After a preliminary examination of their dimensions, we decided not to include these in our sample.

Based on this sample we have examined each model to identify the dimensions, or pillars they have used to substantiate their conceptualization of DT in business organizations. The resulting list of dimensions is later used to compare with our new index to identify how the pillars used in contemporary DT measurements differ from those older ones.

4. Findings

4.1. A contemporary DT index and its dimensions

Using our pilot survey data we applied indicator refinement iteratively and independently for each of the 85 index dimensions. This led to the elimination of 5 items, leaving 80 in the refined index. Following this, each of the index dimensions were fitted in a MIMIC model with the reflective indicators included in the pilot survey for external validation. The RMSEA of models range between 0.20-0.27 and comparative fit index between 0.27-0.63, which seems acceptable for this type of single construct model. Consequently, our new index stands elimination and validity checks with a final list of 80 indicators under 14 dimensions. The dimensions and some example indicators under them are as follows:

D1. Customer relations and marketing operations (9 indicators). Example indicators: "Customer feedback is collected through digital tools", "Digital tools and software are used for ordering".
D2. Cyber security (4 indicators). Example indicators: "Cybersecurity risks are systematically assessed and managed", "Virtual Private Networks (VPN) are used".
D3. Data management tools (4 indicators)

D4. External environment (3 indicators)
D5. Human resources (4 indicators)
D6. Investment and Finance Operations (6 indicators)
D7. Logistics and supply chain operations (10 indicators)
D8. Organizational (5 indicators)
D9. Partnership (3 indicators)
D10. Product development process (4 indicators)
D11. Production operations (3 indicators)
D12. Strategy (6 indicators)
D13. Technological resources (16 indicators)
D14. Top management (3 indicators)

4.2. Established vs emergent dimensions

Our representative sample of six major DT measurement models all had clearly defined dimensions and sub dimensions corresponding to their conceptualization of DT. Despite some differences in their wording it was possible to match these dimensions to each other and to dimensions in our new DT index. The results of this analysis is given in Table 2, where each table cell shows the original name of the dimension in its corresponding model.

According to our findings three of the new index' dimensions do not exist in previous models and should be considered as emergent and marked in Table 2. A fourth dimension (D7) is found in only one of the existing models and considered as a borderline case.

Table 2: Comparison of new index dimensions to existing DT measurement models. Emergent dimensions that do not exist in existing models are marked.

NEW DT INDEX	IMPULS - Readiness Model	Digital Maturity Model	PwC Maturity Model	Industry 4.0 Maturity Model	Industry 4.0-MM (SPICE based)	Maturity and Readiness Model for I4.0
D1: Customer relations and marketing	Data-driven services	Customer Experience	Product and service, Bus. models cust. access	Customers		
D2: Cyber security						
D3: Data mgmt tools		Process Digitization	Data & Analytics as core cap.		Data Governance	
D4: External environment			Compliance, security, legal & tax	Governance		
D5: Human resources	Employees			People		
D6:						

Investment and Finance Operations						
D7: Logistics and supply chain operations			Digitisation and integration of value chains			
D8: Organizational	Smart operations	Org., Collab., Culture & Expertise	Org., employees and digital culture	Operations dimension, Culture dimension	Process Transformation	Smart business processes
D9: Partnership						
D10: Product dev. process	Smart products	Product Innovation				Smart products and services
D11: Production operations				Products	Application Mgmt	
D12: Strategy	Strategy and organization	Strategy		Strategy	Org. Alignment	Strategy and Org.
D13: Technological resources	Smart factory	Information Technology Transform. Mgmt.	Agile IT architecture	Technology	Asset Mgmt	
D14: Top management				Leadership		

5. Discussion and Implications: An extroverted turn in Digital Transformation

Considering the fact that the existing DT measurement models commonly used in the industry were all created between 2015 and 2017, the changes captured in our analysis reflect the shifts in DT concept roughly over the last decade. The results indicate that ten of the dimensions in the new DT index developed in our study already existed in and fully cover the previous models, and thus they continue to be part of the contemporary conceptualization of DT. Therefore it can be said that the DT concept is 'extended' to include new dimensions during the last decade while retaining the old ones.

What does the newly emergent DT dimensions tell us about the broader picture? Our first observation in this regard is that two of these emergent dimensions, the "partnership" dimension and the -borderline case of- "logistics & supply chain"

dimension have a common feature that separates them from other, previously existed dimensions: they are both related to a business' relations with 'external' entities in the environment, i.e. activities across business boundaries. The former is related to business partners and the latter to suppliers and customers. For example, some of the indicators we have found under "partnership" dimension reads "company has sufficient pool of IT partners" and "stakeholders collaborate and engage in digital transformation", whereas some in the "logistics & supply chain" dimension are "company uses blockchain system for managing logistics activities" and "company uses software for integrating supplier side operations". These indicators underline the cross-boundary nature of these two emergent dimensions.

When we further look into the other two emergent dimensions we see that the "investment and finance operations" dimension includes indicators such as "electronic services for financial transactions" and "cryptocurrency" which all concern cross-boundary exchanges. The "cyber security" dimension seems to 'cap' the other emergent dimensions and captures the relevant practices that stems from increasing focus on digitalization that crosses organization boundaries and hence is exposed to the inherent risks of an open Internet.

In addition to the changes in DT at the higher dimensions level, some existing dimensions are seeing changes in the underlying elements, which can be seen by comparing indicators in our new DT index with those in the older DT models. For example, the "organization" dimension now includes indicators related to "inter-organizational information systems". New indicators under the "technology" dimension also highlights penetration of some new technologies, such as blockchain, cloud, and IoT. All of which introduces new security vulnerabilities due to higher exposure to or reliance on third parties. These changes in existing dimensions further highlight the emerging extension of DT across organizational boundaries.

These findings suggest that the main axis of the shift we observe here is one that extends DT concept to be more extroverted. In comparison, dimensions in older models were mostly related to introverted issues such as human resources, management, or technology, which all concern issues within the business boundary (with the exception of well established customer relations dimension). This shift reflects a new business environment where traditional physical boundaries of business organizations are more permeable through information and communication technologies under emergent DT coverage, and consequently, more vulnerable to cyber threats.

This broad change, from a digital transformation focused solely on intra-organizational transformational changes to one which is cross-boundary, has important implications for our understanding and strategizing for DT. On the theoretical side, this finding highlights that this digital transformation should be conceptualized as a change involving extra-organizational elements, best understood as a process involving whole ecosystems. There is also an important practical implication: cyber security is now the

weakest link in this new DT process. To expand their digitalization to include partners, payments, and remote workers, businesses first need to establish their cyber security dimension. A recent global surge in the cyber-security incidents indicates that, in practice, we are far from realizing such prioritization in DT road maps. In addition to their own cyber security, businesses will need to consider their partners' cyber security practices to avoid the spillover of cyber security incidents.

6. Conclusions, Limitations, and Further Research

By means of a formative index development to measure digital transformation in business organization, and comparison of its results with commonly employed measurement models from last decade, this study identified the changing pillars in our broader understanding of this phenomenon. Our findings highlight a fundamental change in digital transformation concept which extends its previously intra-organizational focus with new pillars that embrace its extroverted aspects stemming from inclusion of digital business activities that cross organizational boundaries, reaching out to external stakeholders, and in the process creating new cyber-security vulnerabilities.

Despite identifying a major shift through its findings, our study is limited in the sense that the new digital transformation index is only applied to a small, pilot sample of businesses for validation purposes only. Further and extensive data collection and analysis is necessary if one desires to assess relative importance of the new, emergent digital transformation pillars for business organizations.

In addition, our research scope was not expanded to dig further down into the indicator level differences with existing measurement models. Our indicator level comparison was rather for triangulation purposes. Further research may reveal submerging or emerging elements of digital transformation phenomenon at a finer, indicator level.

Acknowledgements

This research was supported with XXX University research grant no BAP2022-1.

Declaration of Interest

There are no relevant financial or non-financial competing interests to report.

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