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Digitalisation Performance Assessment: A Systematic Review

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Abstract

Organisations are showing a keen interest in digitalisation. However, they are uncertain about how to determine the impact of digitalisation on organisation performance outcomes. This places decision-makers in a challenging position to assess the feasibility and intended performance outcomes of digitalisation. This paper aims to address this important research need and provides the performance indicators, measures, metrics and scales based on a systematic review of 30 selected papers. The results from this review were synthesised using the “adaptive enterprise architecture”, and “results and determinants” frameworks as theoretical lenses. This work will benefit researchers and practitioners interested in studying the impact of digitalisation on organisational performance.

Keywords: digital technology, digital transformation, digitalisation, organisation performance, adaptive enterprise architecture

Introduction

Digitalisation is an emerging trend influencing enterprises to adapt and improve digital capabilities in every aspect to survive and thrive. It enables enterprises to overcome uncertainties and respond to business demands in an effective way (Deepu and Ravi, 2021). Digitalisation is not about only technology adoption, rather, it is about fundamental “change” that occurs in “organisational strategy, business processes, organisational knowledge and the whole socio-technical organisational system” (Park and Saraf, 2016). As the organisation’s internal and external elements and their relationships have been transformed by digital technology (Freitas Junior et al., 2020), it may directly and indirectly impact the enterprise performance outcomes (Meng and Wang, 2020). The uncertain impact of digitalisation on performance places the decision-makers in a challenging position who need to determine the feasibility to invest and predict the intended performance outcomes. Although the influence of digitalisation on performance outcomes has increasingly attracted attention from both scholars and practitioners (Matthess and Kunkel, 2020), however, it is unclear what and how to measure the impact of digitalisation on performance outcomes (Rungi, 2019; Verhoef *et al.*, 2021). This draws our attention to the following key research questions:

RQ1: What are the performance outcomes of digitalisation / digital transformation?

RQ2: What are the measures, scales and metrics of performance outcomes of digitalisation / digital transformation?

RQ3: How to measure the performance outcomes of digitalisation / digital transformation?

To address the above-mentioned research questions, a systematic literature review approach (Kitchenham and Charters, 2007; Rowe, 2018) is used to identify the digital performance indicators (PI) and related elements. The results from this research were framed using the adaptive enterprise architecture (EA) (Gill, 2015) and results and determinants (Fitzgerald et al., 1991) frameworks as theoretical lenses. On the one hand, this research aims to provide a more holistic view from the EA design perspective that may help scholars and practitioners to identify the performance outcome needs of digitalisation when designing and implementing digital initiatives. On the other hand, it provides an

understanding of PI types and metrics to help decision-makers recognise them and make well-informed decisions (Verhoef *et al.*, 2021). Also, it highlights possible gaps for future research in this important and timely area of study.

The paper is structured as follows. Firstly, it discusses the research background. Secondly, it illustrates the systematic literature review research method. Thirdly, it presents the research results. Finally, before concluding, it discusses the research results and important insights.

Research Background and Related Work

Although there is no single agreed definition of digitalisation, however, it commonly interchanges with digitisation and digital transformation, while each term covers a different perspective. Digitisation covers the technical aspect, while digitalisation covers both the social and the technical aspects (Bockschecker *et al.*, 2018). Digital transformation, on the other hand, covers much broader aspect that goes beyond social and technical aspects, including the rapid adaptation of innovative digital technology (Bockschecker *et al.*, 2018). In this paper, we focus on digitalisation, which can be defined as “the manifold socio-technical phenomena and processes of adopting and using these technologies in a broader individual, organisational and societal contexts” (Legner *et al.*, 2017, p. 301). In that context, digitalisation potentially can impact various aspects in organisations. Performance outcome is one of those aspects that will be the focus of this research paper.

Organisation performance can be conceptualised as the ability of organisations to fulfil their aims and goals side by side to their key competitors effectively (Cao and Zhang, 2011), also as the value outcomes from meeting intended determinants. Since the performance measurement should be performed for different classes (dimensions) of organisation performance, those performance outcomes could involve financial and non-financial measures (Wardaya *et al.*, 2019).

Digitalisation or digital transformation requires decision-makers to create a digital vision that explains the need, plan and intended results of digitalisation (Westerman and McAfee, 2012). Consequently, the challenging aspects that decision-makers may face are the uncertainties, risks and disequilibrium (Griffy-Brown *et al.*, 2018; Michelfelder, 2018) of digitalisation influence or impact on organisational design elements and their performance (Park and Saraf, 2016) due to the socio-technical nature of digitalisation. As digitalisation, strategies and other organisational elements are interdependent, digitalisation by itself may not fully explain the complex mechanisms of how it impacts organisational performance (Park and Saraf, 2016).

There are several studies (e.g. Hanelt *et al.*, 2017; Sener and Yuksel 2017; Nandkumar, Mani *et al.*, 2018, Cubric, 2020; Alhassan and Adam, 2021) that refer to digital performance from different perspectives. However, a consolidated and systematic view of digitalisation performance using an appropriate theoretical lens is missing. For instance, organisational performance has been the focus to discuss the impact of digital solutions toward corporate sustainability transformation (Hanelt *et al.*, 2017). Nandkumar’s study discussed market value (Nandkumar *et al.*, 2018), while Sener and Yuksel discussed process performance (Sener and Yuksel, 2017). Also, other studies have focused on either financial performance (Westerman *et al.*, 2014; Sia *et al.*, 2016), production performance (Cao *et al.*, 2019), productivity (Brynjolfsson *et al.*, 2011) or digitalisation investment (Hess *et al.*, 2016). This review will systematically navigate and consolidate the literature on digitalisation/digital transformation performance outcome indicators, measures, metrics, and scales using the theoretical lens of adaptive EA and results and determinants frameworks. This is important to establish a foundation and knowledgebase for developing digital performance theories and systems.

Literature established the use of EA as a way to enhance performance measurements (Hinkelmann *et al.*, 2016; Lange, Mendling and Recker, 2016; Hazen *et al.*, 2017). There are several EA frameworks such as The Open Group Architecture Framework (TOGAF) (Andrew *et al.*, 2016) and Zachman (Zachman, 1987), however, these frameworks originated in the context of traditional architecture methods and ontologies. For instance, TOGAF provides method for developing the architecture. However, it does not explicitly mention the digital and its performance. Whereas Zachman framework provides only generic ontology. Therefore, a contemporary adaptive EA (Gill, 2015) framework has been selected because it has been originated in the context of digitalisation and digital ecosystem, which

is relevant to the scope of this study. It provides comprehensive layers for conceptualizing the digital enterprise. Adaptive EA (Gill, 2015) provides 6 major architecture layers (Interaction, Human, Technology, Environment, Facility, and Security). Adaptive EA discusses the performance element; however, it does not explicitly provide detailed performance indicators or factors. Thus, the results and determinants framework (Fitzgerald et al., 1991) has been used to complement the adaptive EA. The results and determinants framework provides 6 types of factors for performance assessment: competitive, Financial, Quality of Service, Flexibility, Resource Utilization, and Innovation. These are further detailed in the theoretical lens section. One may adopt other theories or frameworks, which could be used to frame similar studies; however, like any other study, this paper is limited to two relevant frameworks (1) adaptive EA and (2) results and determinants for synthesizing and reporting the results and insights. Future studies may use other theories, frameworks and perspectives as appropriate to their research context and scope.

Research Method

This study applied a well-known systematic literature review (SLR) approach (Kitchenham and Charters, 2007; Rowe, 2018) to scan, select, and synthesise the published literature in digitalisation its impact on performance from an enterprise design perspective. Those SLR approaches are reviewed and used as a guide to avoid any possible omissions. For instance, the use of two different frameworks to map and analyse extracted data was inspired by Rowe (Rowe, 2018) SLR strategies to synthesis the extracted data. The quality assessment measures by Dybå & Dingsøy (2008) have also been applied to assure the quality of the selected studies for this review. As noted earlier, this review research also used the adaptive EA (Gill, 2015) and results and determinants (Fitzgerald et al., 1991) as theoretical lenses to synthesis the extracted data from papers to identify the valuable insights from digital enterprise design performance perspectives. This review is conducted as follows:

Research Identification Criteria

Research questions mainly guided our study. Additionally, this review encompassed papers only published in English in the last five years between 2016 and 2021. It provided adequate inclusion of recent literature. Articles that did not support the identified research question(s) were excluded from this review.

Research Selection Strategies

This study included five well-known academic digital databases: IEEEExplore, Scopus, AIS eLibrary, ScienceDirect, and Wiley. The digital databases were systematically searched using the search keywords (digitalisation, performance, impact, effect). Those keywords were used to screen the title, keywords, and abstracts of publications covering the period of 2016 to 2021 to establish research directions based on the recent literature. It is anticipated that studies spread over 5 years provide sufficient coverage. For testing purposes, the initial review in Scopus was conducted by using the search string “(digitali?ation OR digi*) AND performance AND (impact OR effect)”. The purpose of the search string testing was to ensure the identification of related studies. To avoid the risk of restricted query that may automatically eliminate or omit important studies, step 1 is to retrieve all the papers (hits) that have the keywords then manually exclude papers based on the review of paper titles. See figure 1 for detailed screening and selection method.

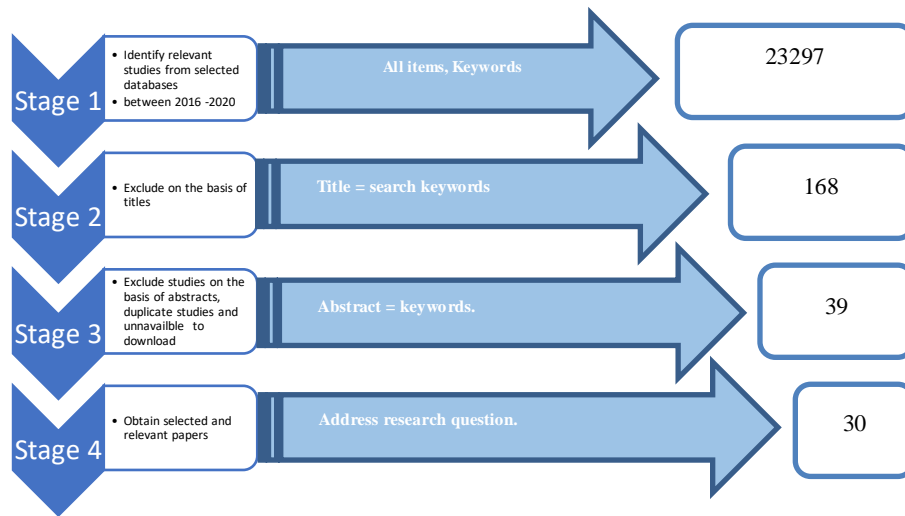


Figure 1: Study Selection Method

Quality Assessment

Based on Dybå & Dingsøyr (2008), the quality assessment criteria were used to assess the selected studies' quality for this research. The assessment criteria are defined in Table 1. The 30 extracted studies satisfied the quality assessment criteria.

Quality criteria
Q1. Is the paper based on research? To identify whether this study is based on research or experts reporting lessons learned.
Q2. Is there a clear statement of the aims of the research? A clear declaration of study's main outcomes and justification for the study was provided.
Q3. Is there an acceptable description of the context in which the research was carried out? A clear description of the industry and nature of the organisation in which the study was conducted.
Q4. Is there a clear statement of findings? An explicit description and discussion of research findings including the credibility of those findings, limitations, relevance to research questions and justification for conclusion.
Q5. Is the study of value for research or practice? The value is identified by the study's contribution to current practice or literature including the identification of new research directions.

Table 1: Quality Criteria

Table 2 provides a detailed overview of the selected studies' overall number retrieved from selected databases at each stage. The majority of retrieved papers were found in the AIS database covering almost 50% of the total selected studies in the last stage.

Database /Screening stage	Stage 1	Stage 2	Stage 3	Stage 4
IEEE	363	57	3	3
Scopus	6074	65	13	9
ScienceDirect	613	8	2	2
AIS	8112	25	18	14

Wiley	8135	13	3	2
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Table 2: Research Result

Theoretical lens:

We used two kernel theories to systematically capture and analyse the review results. On the one hand, adaptive EA (Gill, 2015) has been used, which can be illustrated as “fundamental concepts or properties of an adaptive enterprise situated in its heterogenous networked environment, embodied in its elements, relationships to each other and its environment, and in the adaptive principles of its secure adaptive design, implementation planning, governance and evolution” (Gill *et al.*, 2020, p.175). It has been used because it provides guidance on six architecture layers and underpinning concrete elements (Figure 2): Interaction, Human, Technology, Environment, Facility, and Security layers (Anwar and Gill, 2019). Each layer is organised in terms of its underpinning elements. Firstly, the interaction layer includes the actors and their interactions via different digital touchpoints, channels, and overall journey experience. Channel is a communication medium that organisations offer to their clients, while touchpoint is a stage or point in the process for initiating the interaction using the provided channel. Secondly, the human layer covers the business, information, social and professional architecture domains. Thirdly, the technology layer covers infrastructure, application, data and platform architecture domains. Fourthly, the security layer deals with the security concern of every other element or factor across other layers in the adaptive EA. Fifthly, environmental layer includes PESTEL (Political, Economic, Social, Technological, Environmental and Legal) elements, which is used at the strategic level to analyse macro-environment elements. The aim of this layer is to help decision-makers capturing the sources of opportunities and risks (Witcher and Chau, 2010) when dealing with digital transformation. Finally, the facility layer covers heating, ventilation, air conditioning (HVAC), spatial, energy and ancillary elements. Also, adaptability, in adaptive EA, is achieved through scanning and sensing changes (threats and opportunities), interpreting and analysing them, deciding and responding to those changes for adaptations across EA layers and elements. Adaptive EA was used because it provides a systematic layered approach and concrete elements for designing and evolving digitally-enabled enterprises. Thus, it has been used as a theoretical lens to frame and report research results.

Adaptive EA does not explicitly provide performance factors. Thus, to complement adaptive EA, the results and determinants framework (Fitzgerald *et al.*, 1991) is used, which is one of the common performance measurement frameworks. It has been selected because it provides technology independent clear six generic dimensions or classes for performance measurement: Competitiveness, Financial, Quality of Service, Flexibility, Resource Utilisation and Innovation. This framework is composed of two main types, which are results and determinants. On the one hand, the result’s underpinning dimensions are financial and competitiveness performance measures. This represents the organisations’ final goals (lagging factors). On the other hand, the determinants cover measures related to resource utilisation, innovation, flexibility, and quality performance (leading factors). In a nutshell, adaptive EA provides guidance on the enterprise design layers and elements. The results and determinants framework provides guidance on the performance dimensions, which can be related (performance measurement of adaptive EA) to adaptive EA layers and underpinning elements (see Figure 2).

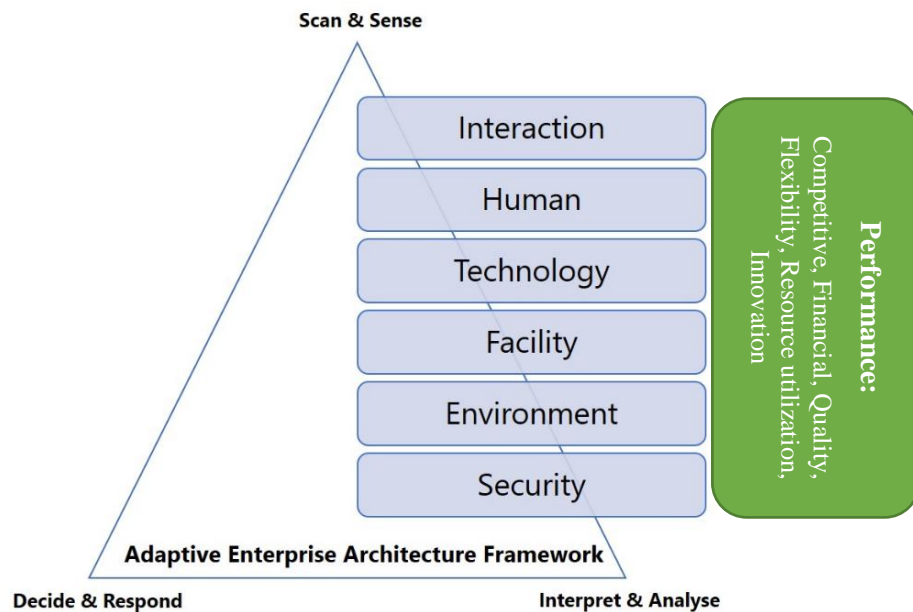


Figure 2: Adaptive EA layers (Gill, 2015; Gill *et al.*, 2020) integrated with Results and Determinants performance dimensions (Fitzgerald et al., 1991)

Results

Thirty relevant papers were systematically selected in this study by applying the SLR method (Appendix A). They were carefully selected and reviewed according to the 4-stage search method described in (Figure 1). Data have been extracted and analysed using the adaptive EA framework (elements and layers) and the results and determinants framework as integrated theoretical lenses (Figure 2) to gain a comprehensive insight into the existing literature to answer the research questions. The extracted digitalisation PIs were carefully reviewed using the adaptive EA elements and layers (see Appendix B, C, D) to review and identify the existing literature support in assessing the performance of the architecture layers and its underpinning elements that represent the enterprise design.

RQ1: What are the performance outcomes of digitalisation / digital transformation?

As noted in the background section, the literature about digitalisation impact on performance outcomes is scattered, e.g. (Hanelt, Busse and Kolbe, 2017; Nandkumar, Mani and Bharadwaj, 2018). It is also not clear how to effectively synthesise it. Thus, we used adaptive EA framework layers and elements as a theoretical lens to systematically navigate and consolidate the scatter digitalisation performance outcomes in the current literature. As such, we extracted data related to performance outcomes of specific digitalisation aspects, using results and determinants framework, then synthesised it to related layers in EA as PI. Also, we categorised each PI as a PI type using six generic performance dimensions from the results and determinants framework (Fitzgerald et al., 1991). For instance, in study A20, we identified and extracted the PI (market share) under the competitiveness performance dimension of the results and determinants framework. This PI measures the impact of market intelligence capability (leveraging market value capture), a digital business capability interpreted as a “business” under the human layer of the adaptive EA. Similarly, other PIs are mapped to the results and determinants framework dimensions and adaptive EA layers. As illustrated in Figure 3, firstly, we found that a large cohort (73%) of the selected studies investigated the financial impact of digitalisation involving financial profitability, cost efficiency or market value indicators. Secondly, 43% explored resource utilisation as a determinant, while only one-third (33%) of the studies focused on the competitiveness outcomes from sales growth and market share perspective. Surprisingly, only 16% of the studies highlighted digitalisation's impact on innovation and 6% considered quality and flexibility performance outcomes. Also, it is important to mention that the majority of the extracted PIs related to the resource utilisation, while just 14 PIs of the extracted PIs were related to Financial (see figure 4). Figures 3 and

4 provide a clear contrast via two different views of the research results. Overall, we managed to extract 51 PIs across different performance dimensions, which will be discussed later in this paper. It can also be observed (see Figures 3 and 4) that count of studies and PIs can be assigned to different and multiple PI types or categories.

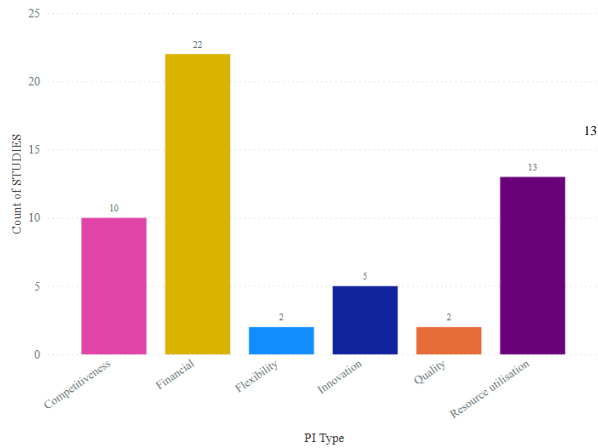


Figure 3: Count of Studies by PI Type

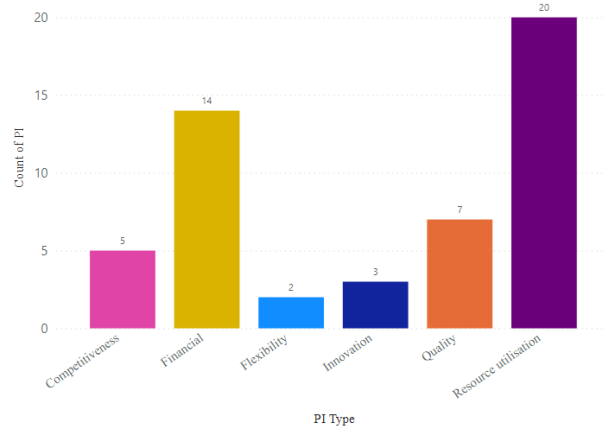


Figure 4: Count of PI by PI Type

Interaction Layer

We extracted 12 PIs related to the interaction layer for digitalisation. It can be observed from Appendix B that the majority of the indicators only address the actors' interaction, and just one indicator has included the influence of channels and touchpoint digitalisation. Most of them are financial and just one indicator related to competitiveness, resource utilisation and flexibility. However, we noticed that only 6 papers (20%) recognised this layer, which clearly highlights gaps in the reviewed studies.

Human Layer

Most of the selected papers (77% of the selected studies - 23 studies) shed light on the outcomes of digitalisation in the human layer (specifically business). As illustrated in Appendix C, we found 46 PIs between results and determinants under the human layer. The majority of those indicators are resource utilisation (37%) as determinants and financial (26%) as result dimensions. Almost all of those financial indicators reported profitability over cost efficiency (10%). On the one hand, the majority of the selected studies (60%) focused on determinant results with 33% on resource utilisation, 17% on innovation, 7% on quality and 3% on flexibility. On the other hand, more than 50% of the selected paper shed light on results, precisely financial outcomes (50%) and competitiveness, with 20% of the selected paper covering result outcomes. Although the majority of those indicators are related to digitalisation in the business layer, we found out that just 17% of the studies mainly focus on the social and professional aspects. However, none of the selected studies recognised the digitalisation of information layer impact on performance.

Technology Layer

In this layer, just 20% of the selected studies (6 papers) recognised the performance outcomes for technology perspective (Appendix D). The vast majority of those studies focus their interest on resource utilisation aspect and financial with 5 and 4 studies respectively. Although papers A5 and A11 are the only studies that recognised the digital infrastructure impact on performance, the rest of the 6 studies reported the impact of digital technology and digital capabilities in general without specifying which elements of the technology layer impact performance outcomes. This seems to draw our attention to another gap in the literature despite the technology being an important part of digitalisation. Results of the review indicate that there are 16 PIs identified from the extracted data associated with the technology layer, with 6 financial, 5 resource utilisation, 3 competitiveness, 1 innovation, and 1 flexibility PI.

Security Layer, Environment Layer and Facility Layer

Unpredictably, we realised that A4 (1 study) emphasised digital technology and supply-chain platform impact on financial and environmental performance. It is mediated by the outcomes coming from “major changes in the modes of production and/or service provision, major changes in consumer demographics, frequent and major changes in government regulations, and short product life cycle” (Li, Dai and Cui, 2020, p. 7) which could represent environment layer. Yet, none of the 30 studies discussed the security and facility regarding performance outcomes, which is a substantial gap to consider along with other highlighted gaps in the existing literature studied in this paper.

RQ2: What are the measures, scales and metrics of performance outcomes of digitalisation / digital transformation?

To further strengthen the study results, we identified and extracted different measures, scales, and metrics related to the type of PI, from the review of 30 selected studies. We mapped the extracted PI into six main dimensions to navigate performance measures using the results and determinants framework. As noted in Figure 5, we found 22 different measures related to six PI types. Almost 27% of the studies reported the profitability indications of the financial performance outcomes, whereas less than 10% indicated the market value and cost-effectiveness. Also, measures related to competitiveness evaluate sales growth, market share and customer base, which are less than 7% of the selected studies reviewed in this paper. The other four dimensions determine the means of performance: 50% of the studies focus on the efficiency of resource utilisation and less than 10% on productivity, integration and autonomy, 10% on the satisfaction of quality and 3% on the degree of efficiency and effectiveness of innovation and flexibility (see Figure 5). Those numbers extracted from appendix B, C and D. In appendix B, return on asset, revenue, and profit (the representation of those rows) are indicators that measure the profitability. Thus, those PIs can assess the degree of 22 different measures.

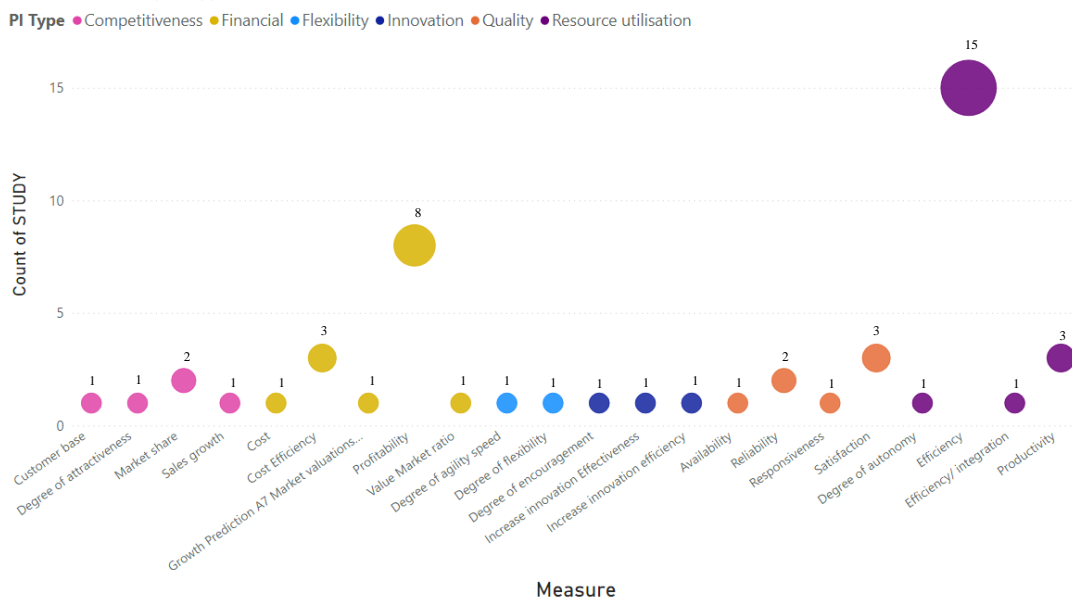


Figure 5: Count of Studies by PI Type and Measure

Scales and metrics vary from financial or the other five performance dimensions. In financial performance, metrics differ from ratio, mean or average depending on the type of scales or units used to measure PI. 45% of the studies have extracted financial performance from the financial reports to measure financial performance either by investigating the financial report numbers of a specific year or comparing them to the previous year’s performance. Furthermore, less than 25% assess the financial dimensions with a Likert scale method of 3, 5 or 7 -step scale to measure financial performance either by comparing to previous year’s performance or competitor’s performance. We also noticed that the other 5 non-financial performance dimensions are mostly evaluated with a Likert Scale method except for some indicators. For example, A5 reported the impact of using a digital network (‘inter-bank’

financial telecommunication network (SWIFT)) to reduce the labour-capital ratio against previous years.

RQ3: *How to measure the performance outcomes of digitalisation / digital transformation?*

RQ2 is mainly focused on the identification of the measures whereas RQ3 is about “how” to measure those measures? Thus, RQ3 discusses the process or method of measurements (e.g., questionnaire, interview). From this review, we found that the current literature seems to measure PI of digitalisation using the questionnaire-based method, analysing the financial report, measuring the ratio of non-financial aspect or qualitative interview method. Surprisingly, the vast majority (63%) measured the PI with the questionnaire-based method, while 30% of the studies extracted the financial data, and 10% calculated the ratio of non-financial indicators. Financial indicators in 9 studies, specifically, discussed analysing extracted data from the financial reports, while most studies (12 studies) discussed the measurement of financial indicators by applying the questionnaire-based method with a view to reflect their financial performance. For example, profit, the most detected financial indicators in the selected studies, has been assessed with a questionnaire-based method to measure the profitability of digitalisation impact except A16.

It can be concluded, based on the above analysis and results, that a questionnaire-based method is preferred over other methods to collect performance-related data, whether financial or non-financial indicators. This is because that questionnaire-based methods seem useful for subjective measure, efficient data collection, and confidentiality, while this might be challenged by low response-rate and desirability bias (Patten, 2016).

Discussion

Over the period of last 5 years, digitalisation has increasingly been gaining attention from academics and practitioners with regards to the study of digitalisation impacts. One aspect that we focus on is digitalisation impact on performance outcomes since there is a current need among organisations “to measure the performance improvements on key performance indicators (KPIs) to facilitate learning and fine-tune the business model” (Verhoef *et al.*, 2021, p. 895). However, there is no consensus among the community about the PIs and the effect of digitalisation on performance outcomes. It has been noticed that the literature on the “digitalisation” is scattered in terms of: (1) the performance outcomes of digitalisation, (2) measures, scales and metrics of performance outcomes of digitalisation and (3) how to measure that performance. Thus, this paper attempted to synthesise the literature discussing the topic of digitalisation performance outcomes. In this review paper, we applied SLR as a research method to systematically recognize and analyse the relevant literature using the adaptive EA and results and determinants framework as theoretical lenses. These lenses helped to systematically identify and map the performance outcomes to each adaptive EA layer and related performance dimensions.

From analysing those papers, we extracted performance outcomes as PIs and associated them with one or more relevant adaptive EA layers and their underpinning element. We also identified the type of each PI across six performance dimensions with the help of results and determinants framework. We also identified PI measures, metrics and scale, where possible and applicable. As we navigated PI using the adaptive EA and the results and determinants as theoretical frameworks to synthesis the extracted data (see Appendix B, C, D), several valuable insights were observed, which are discussed as follows:

Firstly, a large set of 51 PIs was extracted from the 30 selected studies that are related to the digitalisation of interaction, human and technology layers of the adaptive EA. Although, most of those indicators focus on resource utilisation (extracted from 40% of the studies), two-thirds of the studies focused on financial indicators, which are less than 30% of the extracted PIs (see Figure 2-3). It reinforces and confirms that financial indicators and resource utilisation are essential when assessing and planning digitalisation performance outcomes using the adaptive EA.

Secondly, just 23% of the PIs are related to the interaction layer (Figure 6); almost all of it is associated with actors, while just one PI was associated with the digital channel and touchpoint. As a result, this indicates that as a whole interaction layer and, more specifically, touchpoints, channel and experience

have not been explored in great length as factors that could impact performance. This marks the need for further research to determine the digitalisation of interaction PIs and their influence on outcomes.

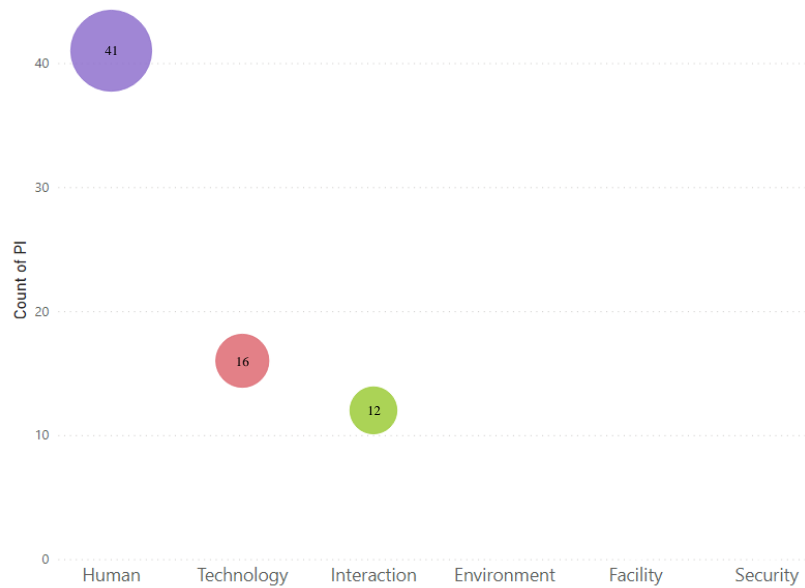


Figure 6: Count of PI by Layer

Thirdly, most of those PIs belong to the human layer of adaptive EA (Figure 6), more precisely they are relevant to the business element (see 70% of those indicators in Appendix C). However, 17% of those indicators discuss social and professional elements. Surprisingly, there is nothing for the information element, which seems an important aspect of digitisation or digitalisation. However, this study detected that most indicators related to the human layer identified several less supported areas, especially the impact of information digitalisation, which clearly highlights the difference in focus in the reviewed selected studies. For instance, this comes to our surprise where information is seen as a core part of digitalisation (Gill, 2021).

Fourthly, it is evident from the analysis (Appendix D) that 20% of the selected studies placed particular interest on technology layers and just 16 PIs are concluded from the extracted data (see Figure 6). However, this indicates a clear gap in literature from the technology perspective (as noted in Appendix D). Apart from the fact that digitalisation is just one factor of many organisational aspects that could impact their performance outcomes directly or indirectly, it also plays a significant role in handling different organisational tasks in the whole system. The digitalisation aspect could be captured as a cross-cutting element in the enterprise design that can be related to other elements in the enterprise.

Fifthly, this review also reveals that the literature of digitalisation impact on outcomes seems to overlook the security, environment and facility layers and underpinning elements. It indicates another important gap that needs to be addressed in the literature to recognise the impact of security, environment, and facility digitalisation on performance.

Sixthly, learning from this review was casted into a consolidated set of PIs, as illustrated in Table 6. Those PIs are grouped under the six dimensions of performance with different aspects of the organisation performance measures. Also, Figure 7 illustrates the number of studies discussing each PI in the consolidated set. This is the first step towards developing a digital performance metamodel, which will be discussed in future directions.

	PI Type	Measure	PI	Source
1	Competitiveness	Market share	Market share	A20 A23 A4 A11 A2 A19
2			Internationalisation performance	A13
3		Sales growth	Sales growth	A4 A12 A23 A24 A15
4		Customer base	Customer acquisition	A20

5		Degree of attractiveness	Sales per customer	A20
6	Financial	Cost efficiency	Enterprise efficiency ratio	A7 A5
7			Operating cost	A3
8			Sales cost	A3
9		Cost	IT investment - infrastructure	A2
10		Growth prediction market valuations	Enterprise stock market measures	A7 A18
11		Market value	Enterprise market value	A16 A18 A28 A29
12		Profitability	Income	A21
13			Operating margin	A5
14			Operating return on assets	A10
15			Return on asset	A3 A7 A9 A10 A11 A29
16			Return on investment	A4 A15
17			Revenue	A6 A19 A20 A29 A5 A11
18			Turnover	A2 A29
19	Profit	A4 A15 A2 A16 A12 A17 A23 A24 A27 A29		
20	Flexibility	Degree of agility speed	Enterprise agility	A17
21		Degree of flexibility	HR flexibility	A12
22	Innovation	Degree of encouragement	Talent management performance	A1
23		Degree of innovation efficiency	Enterprise innovation efficiency	A18
24		Degree of innovation effectiveness	Enterprise innovative effectiveness	A13 A15 A17 A18
25	Quality	Satisfaction	Demand rationalization	A30
26			Purchases quality	A30
27			Customer satisfaction	A23
28		Availability	Availability	A23
29		Reliability	Awareness	A23
30			Brand associations	A23
31	Responsiveness	Consumer attitudes	A23	
32	Resource utilisation	Efficiency	Customer retention	A15
33			Ecotourism performance	A26
34			Enterprise in ecosystem connectivity	A8
35			HR development performance	A1
36			Business flexibility	A14
37			Cost-effective use of IT	A14
38			IT for asset utilisation	A14
39			IT for growth	A14
40			Labor-capital ratio	A5
41			Market value capture	A20
42			Market value creation	A20
43			Operational performance	A25 A30
44			Procurement savings	A30
45			Environmental performance	A4
46			HR efficiency	A12

47		Efficiency/ integration	Process digitisation	A8
48			Work performance	A1
49		Productivity	Employee job performance	A22
50			Information visualisation	A8
51		Degree of autonomy	Business unit IT autonomy	A11

Table 6: Consolidated set of PI digital performance

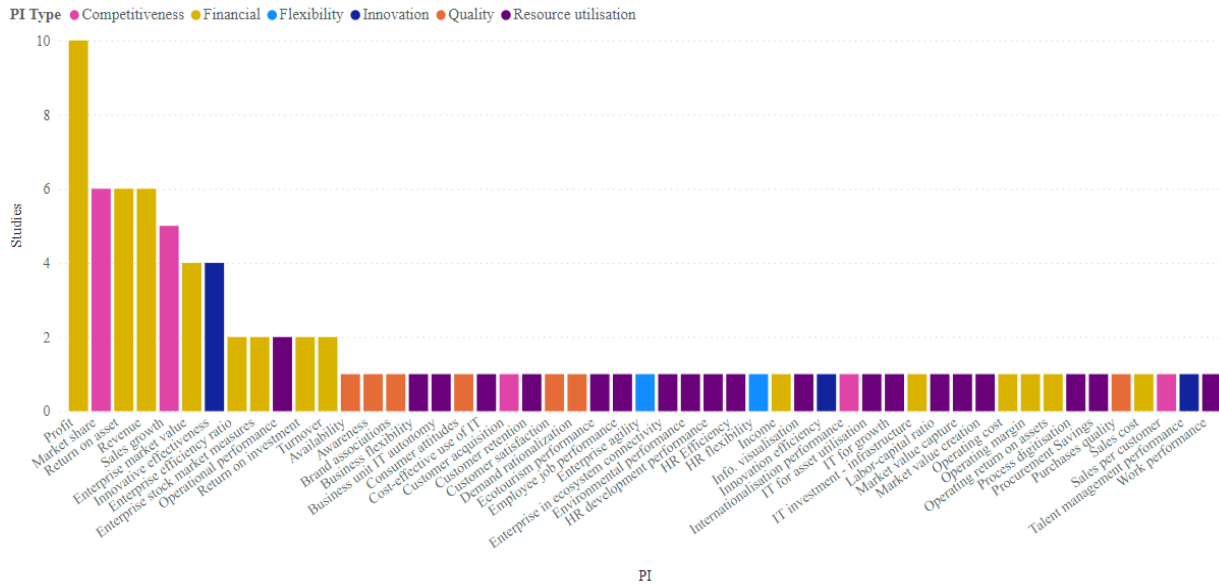


Figure 7: Number of studies discussing each PI

Finally, this paper also reviewed the measures, scales, and metrics that the existent literature has adopted to assess the effect of digitalisation on performance results (see Appendix B, C, D). Measures were analysed and synthesised based on the type of PIs, which were initially extracted using the results and determinants framework. The main extracted measures are profitability, market value, cost-effectiveness, market share, sales, customer base, product attractiveness, efficiency, productivity, satisfaction, responsiveness, availability, reliability, innovation, and flexibility (see Figure 5). Scales and metrics, on the other hand, vary from financial to the other five performance dimensions. While scales for non-financial measures usually use the Likert Scale method of 3, 5 or 7 -step scale, financial measures mainly use financial report numbers or the Likert Scale method. Metrics, on the other hand, differ from ratio, mean or average. However, some of the papers (A4, A15, A17, A24, A29, A30) used the mean as a way to summarise the ordinal or categorical data, which does not seem appropriate from a scientific and statistical analysis perspective. This is because ordinal or categorical data cannot be summarised using the mean. It can be summarised using either mode or median. This clearly indicates the further opportunity for scientific and theory-based research in this important area of research, which needs to have both research rigor and practical applicability. Also, this review indicates that most of the methods (data collection) used in the selected studies were the questionnaire-based method, financial report, ratio of non-financial aspect or qualitative interview method.

In summary, this paper provided a synthesised body of knowledge, insights and research gaps related to digitalisation performance measurement using the adaptive EA and results and determinants framework as a theoretical lens. This intends to provide a systematic adaptive EA design-driven approach to assess the impact of digitalisation on performance. We interestingly noticed that some PIs could be related to multiple EA layers. It highlights the interdependent and integrative impact of digitalisation. This shows another important area of further research because it is not about the digitalisation impact on individual layers or elements; instead, we need to approach and further investigate it using holistic systems thinking approach. This will avoid sub-optimisation of layers, elements or parts of an enterprise when dealing with assessing and planning digitalisation performance

outcomes. The results from this study can be further analysed to design a system of digital performance indicators for a particular industry vertical or enterprise context. This is an interesting future research opportunity where several aspects could be investigated for a specific context such as the relevance and importance of each identified PI to the business nature, size and strategic direction. Moreover, it is important to note here that PIs are of a statistical and analytical nature. Future studies may investigate the use of analytics and artificial intelligence to predict the effective achievement of certain levels (maturity) of digital transformation and relevant performance of an enterprise.

This research paper provided some important insights using the adaptive EA framework and results and determinants framework, which have not been discussed before. However, like similar studies, this research also has some limitations, which are worth mentioning. It is important to note that research is limited to publicly available literature from the selected database. This could have excluded certain studies in digitalisation performance impact. However, this research reviewed a large number of 30 studies to provide adequate coverage of the literature. Further, to ensure the quality of the selected studies in this paper, we also applied the quality assessment criteria, which clearly indicated the acceptable quality of selected papers. It is also important to note here that human error and research bias risks were mitigated through regular meetings and feedback iterations between the researcher and senior author of this paper, who have extensive experience conducting similar types of research. Any conflict about the study selection and review results was resolved through rationalise and constructive argumentation. Thus, we have full confidence in this research results, which seem to open up a number of areas of further research in “digital by design” and its impact on performance outcomes. Further, the contribution of this study is not only limited to a typical SLR study; rather, it also provides an adaptive EA design-driven (EA layers and elements) approach to identify and measure the relevant PI, which has not been discussed before. Hence, it also draws our attention to the need and concept of “digital by design”. Further, it is important to note here that vendor-independent and research-based adaptive EA has been used in this study to avoid any commercial and non-scientific biases.

Conclusion

This paper discussed the important and timely topic of digitalisation impact on organisation performance outcomes. This was done by reviewing a set of 30 selected studies using the adaptive EA and results and determinants framework as theoretical lenses. This review provided a number of insights and areas of further research across five layers of adaptive EA design, which highlighted the need for assessing the impact of digitalisation of (digital EA): digital interaction, digital human, digital technology, digital facility, digital environment, and digital security layers and underpinning elements. Overall, this review's findings highlighted several gaps for future research and the development and evaluation of generic yet adaptable digital performance ontology using scientific research methods. Such generic ontology can be used for developing consistent and adaptive EA driven digital performance assessment and improvement models.

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APPENDIX

APPENDIX A. Selected Studies

ID	Literature Paper
A1	Betchoo, N. K. (2016) 'Digital transformation and its impact on human resource management: A case analysis of two unrelated businesses in the Mauritian public service', <i>2016 IEEE International Conference on Emerging Technologies and Innovative Business Practices for the Transformation of Societies, EmergiTech 2016</i> , pp. 147–152. doi: 10.1109/EmergiTech.2016.7737328.
A2	Rungi, M. (2019) 'Digitalisation: Size Doesn't Matter, Put Focus on Product-and-Service, Not on Process', <i>IEEE International Conference on Industrial Engineering and Engineering Management</i> , pp. 741–745. doi: 10.1109/IEEM44572.2019.8978749.
A3	Meng, F. and Wang, W. (2020) 'Research on the Mechanism of Digitalization to the improvement of Manufacturing Enterprises Performance Based on Mediating Effect', <i>2020 6th IEEE International Conference on Information Management, ICIM 2020</i> , pp. 122–126. doi: 10.1109/ICIM49319.2020.244683.
A4	Li, Y., Dai, J. and Cui, L. (2020) 'The impact of digital technologies on economic and environmental performance in the context of industry 4.0: A moderated mediation model', <i>International Journal of Production Economics</i> , 229(May 2019), p. 107777. doi: 10.1016/j.ijpe.2020.107777.
A5	Scott, S. V., Van Reenen, J. and Zachariadis, M. (2017) 'The long-term effect of digital innovation on bank performance: An empirical study of SWIFT adoption in financial services', <i>Research Policy</i> , 46(5), pp. 984–1004. doi: 10.1016/j.respol.2017.03.010.
A6	Zhou, Y. <i>et al.</i> (2021) 'The impact of HRM digitalisation on firm performance: investigating three-way interactions', <i>Asia Pacific Journal of Human Resources</i> , 59(1), pp. 20–43. doi: 10.1111/1744-7941.12258.
A7	Forcadell, F. J., Aracil, E. and Úbeda, F. (2020) 'The Impact of Corporate Sustainability and Digitalization on International Banks' Performance', <i>Global Policy</i> , 11(S1), pp. 18–27. doi: 10.1111/1758-5899.12761.
A8	Da Silva Freitas, J. C., Gastaud Maçada, A. C. and Brinkhues, R. A. (2017) 'Digital capabilities as key to digital business performance', <i>AMCIS 2017 - America's Conference on Information Systems: A Tradition of Innovation</i> , 2017–August(2015), pp. 1–10.

A9	Fabian, N. E. <i>et al.</i> (2021) 'The value of being different: Industry digital fashion, firm digital skills and financial performance', <i>International Conference on Information Systems, ICIS 2020 - Making Digital Inclusive: Blending the Local and the Global</i> , pp. 0–9.
A10	Chi, M., Zhao, J. and Li, Y. (2016) 'Digital Business Strategy and Firm Performance: The Mediation Effects of E-collaboration Capability', <i>Wuhan International Conference On E-Business: 2016 Proceedings</i> , 58, pp. 86–97. Available at: http://aisel.aisnet.org/whiceb2016/58 .
A11	Queiroz, M. <i>et al.</i> (2020) 'Digital Infrastructure, Business Unit Competitiveness, and Firm Performance Growth: The Moderating Effects of Business Unit IT Autonomy', <i>Proceedings of the 53rd Hawaii International Conference on System Sciences</i> , 3, pp. 5643–5652. doi: 10.24251/hicss.2020.693.
A12	Park, Y. and Saraf, N. (2016) 'Investigating the complexity of organisational digitisation and firm performance: A set-theoretic configurational approach', <i>AMCIS 2016: Surfing the IT Innovation Wave - 22nd Americas Conference on Information Systems</i> , pp. 1–10.
A13	Ortiz de Guinea, A. and Raymond, L. (2018) 'IT Ambidexterity Configurations for Competitive Performance: An Exploratory Study of the Digital Ecodynamics of Small and Medium-Sized Enterprises', <i>MCIS 2018 Proceedings</i> .
A14	Aasi, P. and Rusu, L. (2017) 'Facing the digitalisation challenge: Why organisational culture matters and how it influences IT governance performance', <i>Information Systems Development: Advances in Methods, Tools and Management - Proceedings of the 26th International Conference on Information Systems Development, ISD 2017</i> .
A15	Nwankpa, J. K. and Roumani, Y. (2016) 'IT capability and digital transformation: A firm performance perspective', <i>2016 International Conference on Information Systems, ICIS 2016</i> , pp. 1–16.
A16	Beutel, S. (2018) 'The relationship between digital orientation and firm performance', <i>International Conference on Information Systems 2018, ICIS 2018</i> , pp. 1–9.
A17	Murawski, M. <i>et al.</i> (2018) 'How digital business strategy affects profitability: Opening the “black box” of performance', <i>Americas Conference on Information Systems 2018: Digital Disruption, AMCIS 2018</i> , (2018).
A18	Mani, D., Bharadwaj, A. and Nandakumar, A. (2016) 'Digital centrality and innovation performance', <i>International Conference on Information Systems 2016 Proceedings</i> , pp. 1–13.
A19	Leischnig, A., Woelfl, S. and Ivens, B. S. (2016) 'When does digital business strategy matter to market performance?', <i>International Conference on Information Systems 2016 Proceedings</i> , pp. 1–16.
A20	Leischnig, A. <i>et al.</i> (2017) 'From Digital Business Strategy to Market Performance: Insights into Key Concepts and Processes', <i>International Conference on Information Systems 2017 Proceedings</i> , pp. 0–16.
A21	Saldanha, T. J. V. <i>et al.</i> (2017) 'Leveraging Digitalisation of Services for Performance: Evidence from the Credit Union Industry', <i>International Conference on Information Systems 2017 Proceedings</i> , pp. 0–19.
A22	Guzmán-Ortiz, C. V. <i>et al.</i> (2020) 'Impact of digital transformation on the individual job performance of insurance companies in peru', <i>International Journal of Data and Network Science</i> , 4(4), pp. 337–346. doi: 10.5267/j.ijdns.2020.9.005.
A23	Chinakidzwa, M. and Phiri, M. (2020) 'Impact of digital marketing capabilities on market performance of small to medium enterprise agro-processors in Harare, Zimbabwe', <i>Business: Theory and Practice</i> , 21(2), pp. 746–757. doi: 10.3846/btp.2020.12149.
A24	Wardaya, A. <i>et al.</i> (2019) 'Mediating effects of digital marketing on dynamic capability and firm performance: Evidence from small and Medium-sized Enterprises (SMEs) in Indonesia', <i>International Journal of Recent Technology and Engineering</i> , 8(1C2), pp. 461–464.
A25	Buer, S. V. <i>et al.</i> (2021) 'The complementary effect of lean manufacturing and digitalisation on operational performance', <i>International Journal of Production Research</i> , 59(7), pp. 1976–1992. doi: 10.1080/00207543.2020.1790684.
A26	Mekhum, W. and Torasa, C. (2020) 'Effect of Knowledge Sharing and Digital Management to Performance on Ecotourism in Ranong Province, Thailand', <i>Research in World Economy</i> , 11(5), pp. 481–492. doi: 10.5430/rwe.v11n5p481.
A27	Nasiri, M. <i>et al.</i> (2020) 'Digital-related capabilities and financial performance: the mediating effect of performance measurement systems', <i>Technology Analysis and Strategic Management</i> , 32(12), pp. 1393–1406. doi: 10.1080/09537325.2020.1772966.
A28	Jabr, W. and Zheng, Z. (2020) 'Exploring firm strategy using financial reports: performance impact of inward and outward relatedness with digitisation', <i>European Journal of Information Systems</i> , 00(00), pp. 1–21. doi: 10.1080/0960085X.2020.1829511.
A29	Abou-foul, M., Ruiz-Alba, J. L. and Soares, A. (2020) 'The impact of digitalisation and servitisation on the financial performance of a firm: an empirical analysis', <i>Production Planning and Control</i> , 7287. doi: 10.1080/09537287.2020.1780508.
A30	Patrucco, A. S., Agasisti, T. and Glas, A. H. (2020) 'Structuring Public Procurement in Local Governments: The Effect of Centralization, Standardization and Digitalization on Performance', <i>Public Performance and Management Review</i> . doi: 10.1080/15309576.2020.1851267.

APPENDIX B. Analysis of PI – Interaction layer and elements perspectives

- PI: This refers to a performance indicator.
- Description: This reports either definition or the reason of mapping a PI to a specific architecture layer (A1-30 is referring to selected studies from Appendix A).
- PI Type: This refers to the category of a PI such as Competitiveness, Financial, Quality of Service, Flexibility, Resource Utilisation and Innovation.
- Measure: This refers to measures or facts (data element) with reference to PIs.
- Metrics: The metrics refers to the processing PI measure (facts) using statistical analysis as per scale/unit.
- Scale/unit: The scale or unit of a PI measure such as Likert scale and Currency (\$).
- Source: This refers to a literature source of a particular PI (A1-30 in Appendix A).

- Count: The count of studies discussing a particular PI.
- Metric Description: This refers to the description a metrics such as the mean or rate related to a PI measure.

Actor								
PI	Description	PI Type	Measure	Metric	Scale/Unit	Source	Count	Metric Description
Market share	* Via the level of organisation digitalisation A2 * Via digital ecodynamics elements against competitors A19	Competitiveness	Market Share	Mean A2	3-point Likert A2 7-point Likert A19	A2 A19	2	Mean of market share
Return on asset	In digitalised firm mediating by cost	Financial	Profitability	Rate	\$	A3	1	Return on asset rate
Revenue	Via digital ecodynamics element against competitors	Financial	Profitability	-	7-point Likert	A19	1	
Turnover	Via the level of organisation digitalisation	Financial	Profitability (efficiency)	Mean	3-point Likert	A2	1	Mean of turnover
Profit	General profitability * via the level of organisation digitalisation A2 * "Operating income before depreciation divided by sales" via holistically digitalised organisation A16	Financial	Profitability	Mean A2	3-point Likert A2 \$ A16	A16 A2	2	Mean of profit
Market value	"sum of market value of its common equity, the liquidated value of preferential stock and total debt) divided by the replacement cost of assets (total assets)" via holistically digitalised organisation.	Financial	Market value ratio	Tobin's Q ratio	\$	A16	1	Tobin's Q ratio
Operating cost	As mediating factor in digitalised firm	Financial	Cost Efficiency	Rate	\$	A3	1	Operating cost rate
Sales cost	As mediating factor in digitalised firm	Financial	Cost Efficiency	Rate	\$	A3	1	Sales cost rate
IT investment - infrastructure	Via the level of organisation digitalisation	Financial	Cost	Mean	3-point Likert	A2	1	Mean of IT investment
Enterprise agility	Capability of process flexibility and flexible strategy, customer responsiveness	Flexibility	Degree of agility	Mean	5-point Likert	A17	1	Mean of enterprise agility
Enterprise in ecosystem connectivity	Collaborative process	Resource utilisation	Efficiency	-	-	A8	1	-
Information visualisation	The ability to display data/info visually	Resource utilisation	Productivity	-	-	A8	1	-
Channel								
PI	Description	PI Type	Measure	Metric	Scale/Units	Source	Count	Metric Description
Income	Net income via digitised customer access and core services via market intelligence capability	Financial	Net Profit	Mean	\$	A21	1	Mean of income
Touchpoint								
PI	Description	PI Type	Measure	Metric	Scale/Units	Source	Count	Metric Description
Income	Net income via digitised touchpoint services and core services via market intelligence capability	Financial	Net Profit	Mean	\$	A21	1	Mean of income

APPENDIX C. Analysis of PI – Human layer and elements perspectives

Business								
PI	Description	PI Type	Measure	Metric	Scale/Units	Source	Count	Metric Description
Income	Net income via digitised business transaction, core services and customer services access	Financial	Net Profit	Mean	\$	A21	1	Mean of income
Profit	<p>* Via HR flexibility and efficiency against competitors A12</p> <p>* via innovative new or improved product/services or digital transformation relative to competitors A15</p> <p>* Via innovation & or agility A17</p> <p>* Via digital market capabilities or Determinant Market performance against previous year A23</p> <p>* Via digital market capabilities and dynamic capability A24</p> <p>* Via digital-related capabilities mediated by performance measurement systems in 3 years A27</p> <p>* Via digital servitisation against previous years A29</p>	Financial	Profitability	Ave A12 Mean A15 A17 A24 A27 A29	5-point Likert A12 A17 A23 A24 A29 7-point Likert A15 A23 A24 A29 4-point Likert A27	A12 A15 A17 A23 A24 A27 A29	7	Mean of profit
Revenue	<p>* Natural logarithm of X year revenue of each organisation via digital mature human resource management A6</p> <p>* Via leveraging market value capture and creation relative to competitors A20</p> <p>* Revenue per employee via digital servitisation against previous years A29</p>	Financial	Profitability	Mean A6 A29	7-point Likert A20 A29	A6 A20 A29	3	Mean of revenue
Return on asset	<p>* Via the interaction between corporate sustainability and digitalisation A7</p> <p>* Via digital servitisation against previous years A29</p>	Financial	Profitability	Ratio A7 Mean A29	\$ A7 7-point Likert A29	A7 A29	2	Return on asset ratio/mean
Turnover	Fixed asset turnover via digital servitisation against previous years	Financial	Profitability (efficiency)	Mean	7-point Likert	A29	1	Mean of turnover
Return on investment	Via innovative new or improved product/services or digital transformation relative to competitors	Financial	Profitability (efficiency)	Mean	7-point Likert	A15	1	Mean of return on investment
Enterprise stock market measures	<p>* Price-to-book-value and annual equity returns via the interaction between corporate sustainability and digitalisation A7</p> <p>* Long-term abnormal stock returns via Innovation Efficiency (12 months stock return adjust by risk-free rate) A18</p>	Financial	Growth Prediction A7 Market valuations A18	Ratio	\$	A7 A18	2	Stock/market valuation ratio
Enterprise market value	* “future earnings relative to the current book value” via digitalisation of firm offerings (ratio of the market cap for a firm over the firm’s total assets) A28	Financial	Market Value	Tobin’s Q ratio A28 A18 Mean A29	\$ A18 A28 7-point Likert A29	A18 A28 A29	3	Tobin’s Q ratio/ mean of market value

	<p>* via Innovation Efficiency Effectiveness A18</p> <p>* Market capitalisation via digital servitisation against previous years A29</p>							
Enterprise efficiency ratio	“Ratio of non-interest expenses to total net income” via the interaction between corporate sustainability and digitalisation	Financial	Cost Efficiency	Ratio	\$	A7	1	Enterprise efficiency ratio
Internationalisation performance	“To expand their market by selling services abroad” via digital ecodynamics (Dynamic capabilities + IT ambidexterity) measured by % of total abroad sales	Competitiveness	Market share	Mean	-	A13	1	Mean of internationalisation
Market share	<p>* Via leveraging market value capture and creation relative to competitors A20</p> <p>* Via digital market capabilities or Determinant Market performance against previous year A23</p>	Competitiveness	Market share	-	7-point Likert	A20 A23	2	
Sales growth	<p>* Via HR flexibility and efficiency against competitors A12</p> <p>* Via innovative new or improved product/services or digital transformation competitors relative to competitors A15</p> <p>* Via digital market capabilities or Determinant Market performance against previous year A23</p> <p>* Via digital market capabilities dynamic capability A24</p>	Competitiveness	Sales growth	Ave A12 Mean A15 A24	5-point Likert A12 7-point Likert A23 A24 A15	A12 A23 A24 A15	4	Sales growth average/mean
Customer acquisition	* Acquiring new customers via leveraging market value capture and creation relative to competitors	Competitiveness	Customer base	-	7-point Likert	A20	1	-
Sales per customer	* Via leveraging market value capture and creation relative to competitors	Competitiveness	Degree of attractiveness	-	7-point Likert	A20	1	-
Market value creation	Leveraging Knowledge about customers for offering development via market intelligence capability	Resource utilisation	Efficiency	-	7-point Likert	A20	1	-
Market value capture	Leveraging Knowledge about competitors for pricing via market intelligence capability	Resource utilisation	Efficiency	-	7-point Likert	A20	1	-
Process digitisation	Automate business processes	Resource utilisation	Efficiency/integration	-	-	A8	1	-
Operational performance	<p>* “Production lead time, product quality, process flexibility, process uptime, and production cost per unit” via lean manufacturing + digitalisation competing with competitors A25</p> <p>* “Value adding activities and minimises wait times and waste” via digitalised procurement structural A30</p>	Resource utilisation	Degree of efficiency	Ave A25 Mean A30	5-point Likert A25 A30	A25 A30	2	Operational performance average/mean
Ecotourism performance	Number of visitors via “knowledge sharing related to ecotourism, tourists’ attraction, and digital management system and ICT”	Resource utilisation	Efficiency	Mean/ Median	5-point Likert	A26	1	Mean/ Median Ecotourism performance

Procurement savings	Buying goods and services at appropriate prices, lower or in line with those budgeted via digitalised procurement structural	Resource utilisation	Cost efficiency	Mean	5-point Likert	A30	1	Mean of procurement savings
Customer retention	Relative to competitors via innovative new or improved product/services or digital transformation	Resource utilisation	Efficiency	Mean	7-point Likert	A15	1	Mean of customer retention
HR development performance	Knowledge/ skills/ professional development via digital transformation	Resource utilisation	Degree of efficiency	Mean	4-point Likert	A1	1	Mean of HR development performance
Work performance	Boost productivity/ value of work / responsiveness and adaptation via digital transformation	Resource utilisation	Degree of productivity	Mean	4-point Likert	A1	1	Mean of work performance
Employee job performance	“task performance, contextual performance, and counterproductive behavior” via digital transformation	Resource utilisation	Productivity	-	-	A22	1	-
Demand rationalisation	Ability to bundle the requests from internal customers into frame agreements via digitalised procurement structural	Quality	Satisfaction	Mean	5-point Likert	A30	1	Mean of demand rationalisation
Consumer attitudes	Via digital market capabilities against previous year	Quality	Responsiveness	-	7-point Likert	A23	1	-
Awareness	Via digital market capabilities against previous year	Quality	Reliability	-	7-point Likert	A23	1	-
Availability	Via digital market capabilities against previous year	Quality	Availability	-	7-point Likert	A23	1	-
Brand associations	Via digital market capabilities against previous year	Quality	Reliability	-	7-point Likert	A23	1	-
Customer satisfaction	Via digital market capabilities against previous year	Quality	Satisfaction	-	7-point Likert	A23	1	-
Purchases quality	Buying goods and services that satisfy the needs of the internal clients via digitalised procurement structural	Quality	Satisfaction	Mean	5-point Likert	A30	1	Mean of purchases quality
Enterprise innovation efficiency	Ratio of granted patents to the total of inventors involved in their creation digitised a firm’s innovation portfolio via digitised a firm’s innovation portfolio	Innovation	Degree of innovation efficiency	Ratio	-	A18	1	Enterprise innovation efficiency ratio
Enterprise innovative effectiveness	<p>“Developing and selling new services/products” A13</p> <p>* Via digital ecodynamics (Dynamic capabilities + IT ambidexterity) measured by % of new services sales A13</p> <p>* Via digital transformation A15</p> <p>* Via Digital Business Strategy A17</p> <p>* via digitised a firm’s innovation portfolio measured by (number of new products scaled by its R&D capital) A18</p>	Innovation	Degree of innovation effectiveness	Mean A13 A15 A17 Ratio A18	7-point Likert A15 5-point Likert A17	A13 A15 A17 A18	4	Enterprise innovative effectiveness ratio/mean
Talent management performance	Creativity and talent via digital transformation	Innovation	Degree of encouragement	Mean	4-point Likert	A1	1	Mean of talent management performance

Enterprise agility	Capability of process flexibility and flexible strategy, customer responsiveness via innovation	Flexibility	Degree of agility speed	Mean	5-point Likert	A17	1	Mean of enterprise agility
Social								
PI	Description	PI Type	Measure	Metric	Scale/Units	Source	Count	Metric Description
Return on asset	Net income divided by total assets via e-collaboration capabilities in 3 years	Financial	Profitability	Mean	\$	A10	1	Mean of return on asset
Operating return on assets	“Ratio of operating income to assets” via capabilities of e-collaboration in 3 years	Financial	Profitability	Mean	\$	A10	1	Mean of operating return on assets
Enterprise in ecosystem connectivity	Collaborative process	Resource utilisation	Efficiency	-	-	A8	1	-
Cost effective use of IT	“Extent, efficiency, and value of IT used in the business” via organisational culture	Resource utilisation	Efficiency	Ave	5-point Likert	A14	1	Cost-effectiveness average
IT for growth	“How effective IT is in learning, being innovative, gaining competitive advantage, and changing and improving” via organisational culture	Resource utilisation	Efficiency	Ave	5-point Likert	A14	1	IT effectiveness average
IT for asset utilisation	“How successfully IT has used knowledge-based assets in an organisation” via organisational culture	Resource utilisation	Efficiency	Ave	5-point Likert	A14	1	asset utilisation of IT average
Business flexibility	“How IT has helped the business respond to internal and external” via organisational culture	Resource utilisation	Efficiency	Ave	5-point Likert	A14	1	Business flexibility average
Professional								
PI	Description	PI Type	Measure	Metric	Scale/Units	Source	Count	Metric Description
Return on asset	Net income divided by total assets via digital skills or digital skill and functional skill	Financial	Profitability	Ratio	\$	A9	1	Return on asset ratio
Profit	Via HR flexibility and efficiency against competitors	Financial	Profitability	Ave	5-point Likert	A12	1	Profit average
Sales growth	Via HR flexibility and efficiency	Competitiveness	Sales growth	Ave	5-point Likert	A12	1	Sales growth average
HR efficiency	“Increase in: overtime hours, part-time workers and temporary workers” via IT implementation (spending, use, and training) as mediating factor	Resource utilisation	Degree of efficiency	Ave	Three binary measures	A12	1	HR efficiency average
HR flexibility	“Job rotation, multi-skilling and adoption of flexible working hours” via IT implementation (spending, use, and training) as mediating factors	Flexibility	Degree of flexibility	Ave	Two binary measures Y/N	A12	1	HR flexibility average

APPENDIX D. Analysis of PI – Technology layer and elements perspectives

Infrastructure								
PI	Description	PI Type	Measure	Metric	Scale/Units	Source	Count	Metric Description
Enterprise efficiency ratio	Operating expenses to operating income via digital network SWIFT	Financial	Cost efficiency	Ratio	\$	A5	1	Enterprise efficiency ratio

Operating margin	Gross pre-tax operating profits divided by revenue via digital network SWIFT	Financial	Operation profitability	Ratio	\$	A5	1	Operating margin ratio
Return on asset	Net income divided by total assets in 2 years via digital infrastructure with less business unit IT autonomy	Financial	Profitability	Ave /mean	Growth rate \$	A11	1	Return on asset average/mean
Revenue	* Total sales via digital network SWIFT A5 * via digital infrastructure with less business unit IT autonomy against competitors A11 *in 2 years via digital infrastructure with less business unit IT autonomy A11	Financial	Profitability	Ratio A5 Ave / mean A11	Growth rate \$ A5 5-point Likert A11 / Growth rate \$ A11	A5 A11	2	Revenue ratio/average/mean
Return on investment	* via digital technology or digital technology mediated by supply chain platform in past three years A4 * via innovation, digital transformation or IT capabilities relative competitors A15	Financial	Profitability (efficiency)	Mean	7-point Likert	A4 A15	2	Mean of return on investment
Profit	* via digital technology or digital technology mediated by supply chain platform in past three years A4 * General profitability via innovation, digital transformation or IT capabilities relative to competitors A15	Financial	Profitability	Mean	7-point Likert	A4 A15	2	Mean of profit
Sales growth	* via digital technology or digital technology mediated by supply chain platform in past three years A4 * via innovation, digital transformation or IT capabilities relative competitors A15	Competitiveness	Growth of sales	Mean	7-point Likert	A4 A15	2	Mean of sales growth
Market share	* via digital technology or digital technology mediated by supply chain platform in past three years A4 * via digital infrastructure with greater business unit IT autonomy against competitors A11	Competitiveness	Market share	Mean A4 Ave / mean A11	7-point Likert A4 5-point Likert A11	A4 A11	2	Market share average/mean
Internationalisation performance	“to expand their market by selling services abroad” via digital ecodynamics (Dynamic capabilities+IT ambidexterity) measured by % of total abroad sales	Competitiveness	Market share	Mean	-	A13	1	Mean of internationalisation performance
Business unit IT autonomy	decentralised IT structure (autonomy across: “supplier relations, production and operations, product and service enhancement, sales and marketing, and customer relations”	Resource utilisation	Degree of autonomy	Ave / mean	5-point Likert	A11	1	Mean of autonomy
Labor capital ratio	Employee over assets via digital network SWIFT	Resource utilisation	Efficiency by reduction	Ratio	\$	A5	1	Labor-capital ratio
Customer retention	Via innovation, digital transformation or IT capabilities relative to competitors	Resource utilisation	Efficiency	Mean	7-point Likert	A15	1	Mean of customer retention
Environmental	“reduction of air emission, reduction of wastewater, reduction of solid wastes and improvement of the firm’s environmental situation” via	Resource utilisation	Efficiency	Mean	7-point Likert	A4	1	Mean of environmental performance

performance	digital technology or digital technology mediated by supply chain platform in past three years							
HR efficiency	“increase in: overtime hours, part-time workers and temporary workers” via IT implementation (spending, use, and training) as mediating factor	Resource utilisation	Degree of efficiency	Ave	Three binary measures	A12	1	HR efficiency average
HR flexibility	“job rotation, multi-skilling and adoption of flexible working hours” via IT implementation (spending, use, and training) as mediating factors	Flexibility	Degree of flexibility	Ave	Two binary measures Y/N	A12	1	HR flexibility average
Enterprise innovative effectiveness	“developing and selling new services”/products via digital ecodynamics (Dynamic capabilities + IT ambidexterity) measured by % of new services sales	Innovation	Degree of innovation effectiveness	Mean	-	A13	1	Mean of innovation effectiveness
Application								
PI	Description	PI Type	Measure	Metric	Scale/Units	Source	Count	Metric Description
Return on investment	* via digital technology or digital technology mediated by supply chain platform in past three years A4 * via innovation, digital transformation or IT capabilities relative competitors A15	Financial	Profitability (efficiency)	Mean	7-point Likert	A4 A15	2	Mean of return on investment
Profit	* via digital technology or digital technology mediated by supply chain platform in past three years A4 * General profitability via innovation, digital transformation or IT capabilities relative to competitors A15	Financial	Profitability	Mean	7-point Likert	A4 A15	2	Mean of profit
Sales growth	* via digital technology or digital technology mediated by supply chain platform in past three years A4 * via innovation, digital transformation or IT capabilities relative competitors A15	Competitiveness	Growth of sales	Mean	7-point Likert	A4 A15	2	Mean of sales growth
Market share	via digital technology or digital technology mediated by supply chain platform in past three years	Competitiveness	Market share	Mean	7-point Likert	A4	1	Mean of market share
Internationalisation performance	“to expand their market by selling services abroad” via digital ecodynamics (Dynamic capabilities + IT ambidexterity) measured by % of total abroad sales	Competitiveness	Market share	Mean	-	A13	1	Mean of internationalisation performance
Customer retention	Via innovation, digital transformation or IT capabilities relative competitors	Resource utilisation	Efficiency	Mean	7-point Likert	A15	1	Mean of customer retention
Environmental performance	“reduction of air emission, reduction of wastewater, reduction of solid wastes and improvement of the firm’s environmental situation” via digital technology or digital technology mediated by supply chain platform in past three years	Resource utilisation	Efficiency	Mean	7-point Likert	A4	1	Mean of environmental performance
HR efficiency	“increase in: overtime hours, part-time workers and temporary workers” via IT implementation (spending, use, and training) as mediating factor	Resource utilisation	Degree of efficiency	Ave	Three binary measures	A12	1	HR efficiency average

HR flexibility	“job rotation, multi-skilling and adoption of flexible working hours” via IT implementation (spending, use, and training) as mediating factors	Flexibility	Degree of flexibility	Ave	Two binary measures Y/N	A12	1	HR flexibility average
Enterprise innovative effectiveness	“developing and selling new services”/products via digital ecodynamics (Dynamic capabilities + IT ambidexterity) measured by % of new services sales	Innovation	Degree of innovation effectiveness	Mean	-	A13	1	Mean of innovation effectiveness
Data								
PI	Description	PI Type	Measure	Metric	Scale/Units	Source	Count	Metric Description
Return on investment	* via digital technology or digital technology mediated by supply chain platform in past three years A4 * via innovation, digital transformation or IT capabilities relative competitors A15	Financial	Profitability (efficiency)	Mean	7-point Likert	A4 A15	2	Mean of return on investment
Profit	* via digital technology or digital technology mediated by supply chain platform in past three years A4 * General profitability via innovation, digital transformation or IT capabilities relative to competitors A15	Financial	Profitability	Mean	7-point Likert	A4 A15	2	Mean of profit
Sales growth	* via digital technology or digital technology mediated by supply chain platform in past three years A4 * via innovation, digital transformation or IT capabilities relative competitors A15	Competitiveness	Growth of sales	Mean	7-point Likert	A4 A15	2	Mean of sales growth
Market share	via digital technology or digital technology mediated by supply chain platform in past three years	Competitiveness	Market share	Mean	7-point Likert	A4	1	Mean of market share
Internationalisation performance	“to expand their market by selling services abroad” via digital ecodynamics (Dynamic capabilities + IT ambidexterity) measured by % of total abroad sales	Competitiveness	Market share	Mean	-	A13	1	Mean of internationalisation performance
Customer retention	Via innovation, digital transformation or IT capabilities relative competitors	Resource utilisation	Efficiency	Mean	7-point Likert	A15	1	Mean of customer retention
Environmental performance	“reduction of air emission, reduction of wastewater, reduction of solid wastes and improvement of the firm’s environmental situation” via digital technology or digital technology mediated by supply chain platform in past three years	Resource utilisation	Efficiency	Mean	7-point Likert	A4	1	Mean of environmental performance
HR efficiency	“increase in: overtime hours, part-time workers and temporary workers” via IT implementation (spending, use, and training) as mediating factor	Resource utilisation	Degree of Efficiency	Ave	Three binary measures	A12	1	HR efficiency average
HR flexibility	“job rotation, multi-skilling and adoption of flexible working hours” via IT implementation (spending, use, and training) as mediating factors	Flexibility	Degree of flexibility	Ave	Two binary measures Y/N	A12	1	HR flexibility average
Enterprise innovative	“developing and selling new services”/products via digital ecodynamics (Dynamic capabilities	Innovation	Degree of innovation	Mean	-	A13	1	Mean of innovation effectiveness

effectiveness	+ IT ambidexterity) measured by % of new services sales		effectiveness					
Platform								
PI	Description	PI Type	Measure	Metric	Scale/Units	Source	Count	Metric Description
Return on investment	* via digital technology or digital technology mediated by supply chain platform in past three years A4 * via innovation, digital transformation or IT capabilities relative competitors A15	Financial	Profitability (efficiency)	Mean	7-point Likert	A4 A15	2	Mean of return on investment
Profit	* via digital technology or digital technology mediated by supply chain platform in past three years A4 * General profitability via innovation, digital transformation or IT capabilities relative to competitors A15	Financial	Profitability	Mean	7-point Likert	A4 A15	2	Mean of profit
Sales growth	* via digital technology or digital technology mediated by supply chain platform in past three years A4 * via innovation, digital transformation or IT capabilities relative competitors A15	Competitiveness	Growth	Mean	7-point Likert	A4 A15	2	Mean of sales growth
Market share	Via digital technology or digital technology mediated by supply chain platform in past three years	Competitiveness	Market share	Mean	7-point Likert	A4	1	Mean of market share
Internationalisation performance	“to expand their market by selling services abroad” via digital ecodynamics (Dynamic capabilities + IT ambidexterity) measured by % of total abroad sales	Competitiveness	Market share	Mean	-	A13	1	Mean of internationalisation performance
Customer retention	Via innovation, digital transformation or IT capabilities relative competitors	Resource utilisation	Efficiency	Mean	7-point Likert	A15	1	Mean of customer retention
Environmental performance	“reduction of air emission, reduction of wastewater, reduction of solid wastes and improvement of the firm’s environmental situation” via digital technology or digital technology mediated by supply chain platform in past three years	Resource utilisation	Efficiency	Mean	7-point Likert	A4	1	Mean of environmental performance
HR efficiency	“increase in: overtime hours, part-time workers and temporary workers” via IT implementation (spending, use, and training) as mediating factor	Resource utilisation	Degree of Efficiency	Ave	Three binary measures	A12	1	HR efficiency average
HR flexibility	“job rotation, multi-skilling and adoption of flexible working hours” via IT implementation (spending, use, and training) as mediating factors	Flexibility	Degree of flexibility	Ave	Two binary measures Y/N	A12	1	HR flexibility average
Enterprise innovative effectiveness	“developing and selling new services”/products via digital ecodynamics (Dynamic capabilities + IT ambidexterity) measured by % of new services sales	Innovation	Degree of innovation Effectiveness	Mean	-	A13	1	Mean of innovation effectiveness