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A Framework for Continuous Assessment of IT Value in Industry 4.0

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Abstract. Assessing the value of information technology (IT) is a priority to modern organizations and one of the most challenging. The topic is studied for decades but the continuous nature of digital transformation in industry (DTI) added a new dimension to the problem. This paper presents a framework to capture IT value over time, supporting industries in (1) monitoring the outcomes of their digital transformation and (2) evaluating the need for new investments. The framework is inspired in the literature of IT value and extended to the dynamic, integrated, and boundary spanning logic of Industry 4.0. The difficulty to prove the holistic value of IT investments is an obstacle to the necessary developments in industry. Moreover, similarly to DTI, also IT value assessment is multidimensional and should be the result of an ongoing evaluation supported by evidence. Our proposal offers a starting point to create new tools to assist C-level managers steer their investments and make visible the inevitability of digitalization to compete.

Keywords: IT Value, Continuous Assessment, Industry 4.0.

1 Introduction

Sustainable digital transformation requires to achieve social, economic, and environmental outcomes (Felsberger, Qaiser, Choudhary, & Reiner, 2020; Kamble, Gunasekaran, & Gawankar, 2018). Industry worldwide is interested in this trend that promises to transform organizations using information technologies (IT) and redesigned business processes (G. Popkova & Sergi, 2018). Industry 4.0 is a possible term to describe the phenomena that "*is a long term programme, and it is envisaged that it will only become fully implemented from about 2025 onwards*" (Smit, Kreutzer, Moeller, & Carlberg, 2016). Therefore, new frameworks are necessary to support industry managers in their vision and assessment of digital transformation.

The outcomes of Industry 4.0 can be measured (Felsberger et al., 2020); however, the concept of value is complex and several researcher claimed for integrated approaches. For example, in the extant literature of IT value (Davern & Wilkin, 2010). Assessing the value of IT is even more important in the digital transformation era that involves major investments and long term vision (Smit et al., 2016). Surprisingly, integrated approaches to assess the value of IT in Industry 4.0 are still rare, particularly when it is necessary to go beyond the scope of individual projects and create routines of assessment that support continuous investments in IT. Important governance frameworks like COBIT 2019 suggests regular meetings to evaluate how digitalization can be adopted (ISACA, 2019), requiring advanced data analytics capabilities and useful indicators to support decisions.

To address the above-mentioned challenges, this paper puts forward the following research objective: *propose an integrative framework to assess IT value in Industry 4.0*. These results are the first step to create a digital platform that delivers a comprehensive assessment of digital transformation over time. The remainder of this paper is structured as follows. Next, background literature on Industry 4.0 and its adoption are offered. Section 3 begins with a revision of IT value and provides the foundations for the new framework included in Section 3.2. The paper closes stating the main conclusions, the study limitations, and the opportunities for future work.

2 Background

2.1 Industry 4.0

Digital transformation in industry (DTI) is now a top priority for different zones of the globe (G. Popkova & Sergi, 2018; L. Li, 2018; Xu, Xu, & Li, 2018). It can be defined as the development of smart factories that provide smart services and smart products to satisfy the needs of each client (Wang, Wan, Li, & Zhang, 2016). Characterized by the extensive use of advanced resources of information and communication technologies, Industry 4.0 is also a social transformation process with major impacts in work practices (Melnyk, Kubatko, Dehtyarova, Matsenko, & Rozhko, 2019).

Industry 4.0 was originated by a technology strategy project of the German Government aiming to promote innovation and improve competitiveness (Reischauer, 2018). The term was firstly used in the Hannover fair in 2011 and, in April 2013, a final report about the development of Industry 4.0 was published. The concept become popular in many countries and is a growing research stream (Liao, Deschamps, Loures, & Ramos, 2017).

Important guidelines and recommendations for this initiative have been proposed (Acatech, 2013), describing how companies can create intelligent and autonomous networks by connecting machines, systems, and IT resources. According to Acatech (2013), "[i]*ndustrie 4.0 will also result in new ways of creating value and novel business models. In particular, it will provide start-ups and small businesses with the opportunity to develop and provide downstream services*".

Upgrading to Industry 4.0 requires vertical, horizontal, and end-to-end digital integration of manufacturing systems (Brettel & Friederichsen, 2014). Moreover, industries must foster digital engineering throughout the product lifecycle and, lastly, the decentralization of production and computing resources. Through complex innovation processes based on disruptive technologies (e.g., cloud, mobile, artificial intelligence, robotics), numerous companies will be forced to rethink their strategy, processes, and position through their business value chain, and how they think about the development of new products and introduce them in the market, adjusting the marketing and distribution actions. According to Klaus Schwab, there are four main effects on business across industries (Schwab, 2017), namely, *(1) customer expectations are shifting, (2) products are being enhanced by data, which improves productivity, (3), partnerships are being created as companies learn the importance of new forms as collaboration, and (4) operating models are being transformed into new digital models*. Products and services are being empowered with digital capabilities. Intelligent sensors are now able to monitor information in real time, providing statistical information of performance (Oztemel & Gursev, 2020). Nevertheless, Industry 4.0 requires proper planning to evolve organizational maturity (Schumacher, Erol, & Sihn, 2016), as presented in the next section.

2.2 The Adoption of Industry 4.0

Industry 4.0 is expanding in the global manufacturing industry but there are also barriers, particularly for small and medium sized companies (Moeuf, Pellerin, Lamouri, Tamayo-Giraldo, & Barbaray, 2018), as presented in Figure 1.

Fig. 1. Challenges faced by Small and medium enterprises when adopting I4.0

Important challenges arise when designing a 4.0 industry architecture, requiring a system of systems and models that continuously adapt (Panetto, Iung, Ivanov, Weichhart,

& Wang, 2019). The first is "*due to the necessity of defining the required business entities: how these entities participate during the value creation process can be challenging to map and requires the perception of the real implication within the value chain network. The second challenge pertains systems integration and interoperability*" (Hernández et al., 2020). A deep restructuring of IT and work organization is possible, but the lack of standardization, workers skills, insufficient financial resources, and the possible security issues must be evaluated in detail (Bauer et al., 2016; Hernández et al., 2020). To understand IT value applied to Industry 4.0, some reflection questions seek for answers by the companies that want to adopt it (Goldstein, Katz, & Olson, 2003):

- *"How much technology do I need, and why?*
- *Am I spending too much on technology?*
- *What benefits will the institution realize?"*

It became clear that the decisions to invest in Industry 4.0 require a continuous analysis of costs and benefits. However, the analysis of value is extremely difficult and has been suggested that companies "*must identify a clear business objective, start small, focus on one area to begin with, get that area right, and prove the value of digital transformation before expanding to other parts of the enterprise*" (Demirkan, Spohrer, & Welser, 2016). How to assess IT value in Industry 4.0 is the focus of the next section.

3 IT Value Assessment in Industry 4.0

3.1 The Traditional Approach

There is a temporal gap between IT costs and its benefits realization that must be taken into account (Töhönen, Kauppinen, Männistö, & Itälä, 2020). For example, IT that was newly implemented is expected to have different evaluation when comparing to another system already fully implemented and learnt by all the members of a team. Depending on the lifecycle stage of the IT investment, benefits vary.

Figure 2 describes a sequence of steps for value assessment of IT in Industry 4.0 that we identify in the literature.

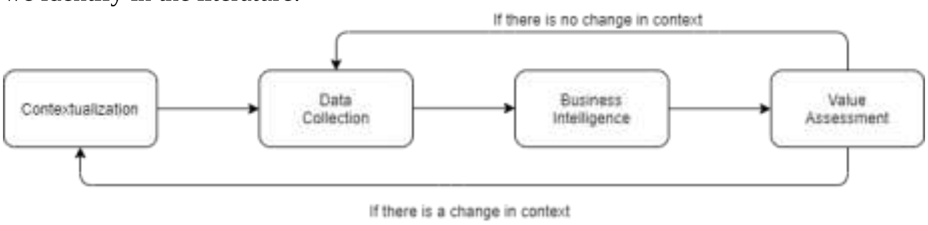

Fig. 2. – Diagram representing the IT Value assessment flow.

Four main phases are pinpointed. First, contextualization, depends on the setting in which IT is being implemented. For example, solutions that automate manufacturing lines using advanced sensors and artificial vision may be relevant for quality management, while systems involving augmented reality for product service may require an evaluation based on customer satisfaction. Subsequently, data collection needs to include both tangible (e.g., IT spending, improvement measures) and intangible elements (e.g., improved worker satisfaction and motivation). Business intelligence techniques are then essential to capture value of digitalization. When the context changes or the company requires an evaluation (e.g., new IT system introduced), the cycle must restart. A review on each of the four phases is presented below.

Context.

Value assessment is related to a particular context of digital transformation. Therefore, managers must determine the priorities of the company stakeholders since their definition of value may vary (Marthandan & Meng Tang, 2010). Improving sales, customer satisfaction, or accident prevention are examples of concerns. The clarification of business strategy is vital to the success of IT implementation and evaluation, as showed by Kyratsis, Ahmad, and Holmes (2012). These authors conducted a study addressing technology adoption on 11 health Trusts concluding that choosing IT before breaking down priorities tend to lead to unsuccessful implementations.

The type of IT system is another important variable. G. Li, Yang, Sun, and Sohal (2009) performed a hypothesis testing based on data collected from 182 companies to explore the type of value generated by a supply chain management system. Other authors focused their efforts in developing four layers that assist in evaluating the value generated by multi-firm IT (Thomas & Johnson, 2012). The examples are vast revealing the different possible benefits of IT that may be deliberate (achievement of organizational goals) or emergent from their use and adaptation by users.

Table 1 illustrates some examples of IT value in different contexts.

Table 1. Examples of research of IT value in different contexts

Contextualization	Description	Authors
IT Type	Multi-firm Integration IT	(Thomas & Johnson, 2012)
	Quantifying the financial impact of cloud IT investment	(Rosati, Fox, Kenny, & Lynn, 2017)
	How established companies leverage IT for value co-creation	(Sobczak & Berry, 2007)
Priority	Priority Ranking for IT	(Schreieck & Wiesche, 2017)
	Role of competitive priorities on IT implementation	(Haro, Basáez, & Aranda, 2019)
Organization	IT value management model for Universities	(Pereira, Ferreira, & Amaral, 2018)

Data collection to assess IT value usually involve costs and benefits, as described in the next two subsections.

Costs.

G. Li et al. (2009) define direct costs as those costs that can be reasonably measured and allocated to specific output, product, or work activity, while indirect costs cannot.

Direct costs are easier to identify in a precise way and can be classified into 4 categories (Flanagan & Marsh, 2000):

- Hardware: The costs related to the purchase of computers and equipment.
- Software: The cost related to the acquisition and maintenance of software.
- In-House Labor: The cost of labor used in the operations related to IT.
- External Providers: The cost of services hired to external entities.

These four categories of direct costs need to be wide enough to be common to every company. Then, it is necessary to divide them in sub-categories to be chosen and filled by the CIO according to their unique case. This approach is also intended to be used for indirect costs and benefits. Nevertheless, indirect costs cannot be underestimated (Love, Ghoneim, & Irani, 2004). Hochstrasser (1994) defends that they can be up to four time greater than the direct ones. Contrasting to direct costs, indirect measures are very difficult to assess and categorize and have been a topic of research for the past decades. Activity based costing is a possible solution to adopt (Raz & Elnathan, 1999).

Table 2. Examples of indirect costs to measure IT value in different contexts (Love et al., 2004)

Typology	Method
Time	Time tracking practices such as timesheets
Learning Costs	
Effort and Dedication	
Costs of Resistance	Satisfaction surveys and performance monitoring
Deskilling	
Reduction in knowledge base	
Missed-Costs	Reference Guide for IT associated expenditure
Moral Hazard	Inquiries directed to the decision makers

Benefits.

It is difficult to find a complete benefit categorization model for IT. However, the categorization made by Weill (1992) may assist in the IT value analysis:

- *Strategic* IT contributes to the position of a company as part of the market whether to increase competitive advantage or to increase market share.
- *Informational* IT developed to optimize information related operations.
- *Transactional* IT focusing on cutting on labor costs by automating transactional processes. Mirani and Lederer (1998) selects this classification for the development of a benefit measuring classification, while Mooney, Gurbaxani, and Kraemer (1996) also introduces the concept of automation and transformational effects of IT.

Irani (2002) defends that focusing benefit evaluation on a financial point-of-view is inefficient. The author suggests two additional levels: tactical that refers to the systems used to achieve the business objectives, such as improvements in productivity; and operational, which refer to the benefits in the core of the operations to keep the business running.

However, the pervasiveness of IT is creating difficulties to value assessment. The emphasis in automatizing business processes is shifting to digital transformation of supply chains and products, as presented in the new logic of innovation (Yoo, Henfridsson, & Lyytinen, 2010). This change in IT led to an expansion of its costs (e.g., renting, pay-per-use) and impacts, making the prior categorizations restrictive. The recent proposal presented by Töhönen et al. (2020) suggests classifying outcomes according to organizational performance, process (e.g., efficiency and effectiveness), and individual users. This vision can be expanded to the societal outcomes (Majchrzak, Markus, & Wareham, 2016).

Business Intelligence.
Chen, Chiang, and Storey (2012) defines Business Intelligence (BI) as "*technologies to analyze critical business data to help an enterprise better understand its business and market and make timely business decisions*". Assessing IT in increasingly digitalized companies requires exploring a large amount of input data. New tools can be developed to explore contextualization, and the more recent contributions in IT value assessment to assist managers. Nevertheless, value is not a static measurement. To be valid to assist managers, BI must be able to capture value over time, according to the needs of the stakeholders. Static evaluation is lacking since the context in which IT is inserted has a great impact on its business value, can change unexpectedly, and depends in the users adaptation of IT and the business processes (Paul, 2007). The our literature review allowed us to propose an updated framework, as described in the next section.

3.2 The New Logic of IT Value Assessment in Industry 4.0

The new logic requires a continuous assessment of IT value, not restricted to punctual changes in context (e.g. process redesign, new IT investment). Moreover, there are evidences suggesting that "*IT alone is not able to sustain a competitive advantage*" (Perez-Arostegui, Benitez-Amado, & Tamayo-Torres, 2012), requiring a boundary spanning perspective and the creation of capabilities in the organization to take advantage of digital transformation (Nwankpa & Roumani, 2016). Both, IT *resources* and the investments in the organizational *capabilities* driven by IT are crucial to generate value. Figure 3 presents the proposed framework.

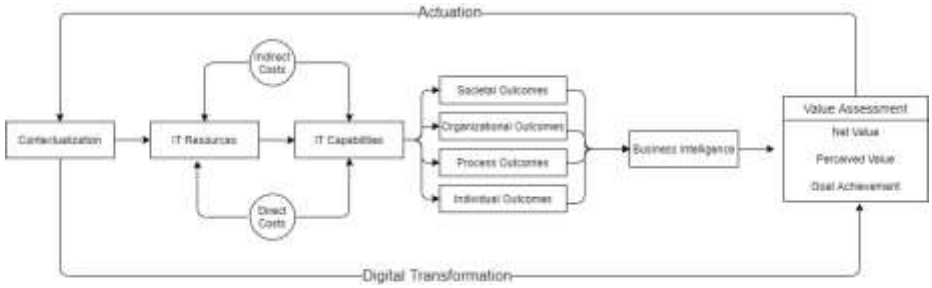

Fig. 3. Framework for Continuous IT Value Assessment in Industry 4.0.

Figure 3 summarizes the extension proposed by the authors to the traditional static approach of IT value assessment. The framework suggests a cyclic evaluation and improvement (Deming, 1988; Shewhart, 1939) of IT systems tailored to a specific context of the industry. Contextualization is followed by the economic assessment of IT resources (e.g. IoT acquisition, enterprise systems, manufacturing execution systems) and capabilities (Goh & Arenas, 2020; Nwankpa & Roumani, 2016).

The lens to evaluate IT value in Industry 4.0 are not restricted to projects or departments. In fact, there are new drivers to invest in digital transformation that expands the boundaries of the organization to more complex supply chains, societal challenges, and human protection (Ghobakhloo, 2018; Peruzzini, Grandi, & Pellicciari, 2020; Savastano, Amendola, Bellini, & D'Ascenzo, 2019). Business intelligence will need to include the value perceived by the systems users in combination with the achievement of desired organizational goals and the net value of digital transformation (Töhönen et al., 2020).

4 Conclusions, Limitations, and Next Steps

This paper presented a framework for the continuous assessment of IT value in Industry 4.0. The results are based on a literature review of IT value and three main trends found in Industry 4.0, namely (1) the long-term effect of digital transformation in industry, (2) the boundaryless nature of change that impacts the entire society, and (3) the combination of assessment perspectives. The latter incorporates the users perceived value, the goal achievements according to the desired strategy, and the net value.

Our exploratory research has limitations that must be stated. First, despite the care taken in the selection of the literature sources, this is the version of the framework. Second, the focus of our study is Industry 4.0. The concept of IT value may be different in other sectors of the economy, for example, services or Government administration. Third, this research is essentially explorative, aiming to provide the foundations for a new system to support C-level executives in their decisions. Therefore, the next steps of our research include (1) the development of an IT platform to record and continuously evaluate digital transformation data, and (2) testing the proposed framework in industries adopting Industry 4.0. Two companies already confirmed their interest in supporting the implementation of the framework and validate if the new logic proposed in this paper is more effective to capture IT value when comparing to the static analysis of particular projects and time frames.

IT value is difficult to assess in yearly reports or ad-hoc measurements. Moreover, when used independently, current evaluation approaches (perception, goal achievement, net value) are limited. For example, users may perceive IT value according to the use at that moment, goals may have been achieved but its value depends on the capacity of establishing those goals (and may not have a direct relation to IT investments), and net value is extremely dependent on time because some costs/benefits only become visible in the future. It is possible and desirable to explore synergies combining multiple of levels of analysis (internal/external to the organization), forms of value, and progress over time. The proposed approach seems promising to assist managers' decisions in uncertain and dynamic environments and create new BI tools that capture the all-inclusive value of DTI.

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