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Business Processes Digitalization as a Resolution Direction for Digital Operations Challenges in Digital Supply Networks

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Abstract

Supply chain maturity models urge increased collaboration among supply chain participants to achieve sustained competitive advantage through operational end-to-end visibility and transparency. Digital solutions provide the tools and technologies to enable Digital Supply Networks through inter-connectivity among supply network partners. A major challenge in improving digitalized operations is the divergence between 'official' business processes that are mapped out with accountabilities assigned and the 'de facto' business processes that are executed. During business processes optimization and IT system enhancements, this mismatch between documented versus tribal business processes results often in inefficient, ineffective, and if not addressed early, infeasible digital solutions. In this paper, the authors outline challenges and their root causes by discussing possible resolution directions in the dimensions of organizational change management (e.g., connected customer), IT systems gaps (e.g., composable applications), and common datasets for digital operations and business process mining applications (e.g., digital twins).

Keywords

Business-IT Alignment; Business Processes (Re-)engineering; Digitalization; Digital Operations; Digital Supply Networks; Digital Technologies.

1. Introduction

To improve the agility and resilience to disruptions of supply network operations enterprise decision-makers across all industries continue to invest heavily in Information Technology (IT) [1]. From a technological perspective, it can be expected major improvements due to decades of exponential advances in data processing power (Moore's Law) [2], volume of data transferability (Butter's Law) [3, 4], and storage density per dollar (Kreider's Law) [5]. However, for several years, before being unveiled by the recent pandemic's disruptions, supply chain innovation and performance have deteriorated for a majority of enterprises according to industry observers [6]. Assessing the effect of COVID-19 on supply chain performance, one observation is the failure of integrated supply chain IT solutions to provide "agility" [6].

Supported by anecdotal evidence of supply chain operations, the single most important supply chain management system is Microsoft Excel for its ubiquitous availability, versatility, and speed of adaptability. Both practitioners and researchers, seem to focus on a technology solution to a problem that is neither well documented nor researched in-depth. This paper aims to highlight the gaps in research and practice for Business Process Digitalization efforts in the context of Digital Supply Networks.

To achieve this objective, two guiding hypotheses are formulated:

- The available academic and grey literature focuses on interpreting supply networks' digitalization efforts as a technological challenge and provides frameworks and methodologies accordingly.
- There remain significant gaps in academic research and industrial practice to address the interplay between business processes and (digital) technologies (i.e., business-IT alignment).

To address these hypotheses, this paper provides a background on the state-of-the-art of Digital Supply Networks in Section 2. The research and practice gaps, as well as current approaches to bridge business processes and digital technologies, are reviewed in Section 3. Section 4 presents practical use cases for common pitfalls in business processes and digital technologies integration efforts. Section 5 provides discussion and research agenda, and the paper concludes in Section 6 with final reflections.

2. Background

Digital Transformation is on the top of the priority list for most manufacturing companies and their supply networks. Many are overwhelmed and struggling with the transition and tend to approach it mainly from a technological perspective (aka. 'can we do it' versus 'should we do it'). Selecting an appropriate reference architecture for information systems integration and/or interoperability, and enabling frameworks and technologies (e.g., cybersecurity, internet-of-things, end-to-end connectivity, blockchain, big data, predictive analytics) for such endeavour is not an easy task. To some extent, this can potentially be traced back to the (over-)emphasis on "technology" when digital transformation topics are covered in the news and many academic papers. Often, technological innovation is in the focus and highlighted as the primary and at times only objective of *Digital Transformation* in the manufacturing industry and supply networks. However, the focus should be beyond technology adoption and aimed at developing "digital capabilities".

However, this "techno-centric" approach is doomed to fail in many cases if the underlying business processes are not critically evaluated and adapted to the changing (industrial) environment. Business processes should be properly (re-)engineered before being "digitalized" to exploit higher effectiveness levels enabled by the capabilities of the carefully selected digital technologies. Incorporating digital technologies such as smart sensor systems, 5G-networks, robotic process automation, cloud computing, data analytics, etc. requires rethinking the existing business process and envisioning the impact of their enabling digital technologies on a broader scale to capitalize on their digitalization opportunity.

In the following, this paper briefly reflects on the current state-of-the-art in the related topics of business process modelling and (re-)engineering and digital transformation, and the digital technologies and their implementation frameworks available to support successful business processes digitalization.

2.1 Business Processes & Digital Transformation

Digital Transformation refers to the increase of digitalized business processes in an enterprise or supply chain resulting in the adoption and integration of information, communication, and operational technologies to create new and enhanced digitally-enabled operations. Furthermore, the application of business process optimization and re-engineering techniques has been recognized as a prerequisite for successful business processes digitalization to offer a high degree of contextuality and specificity to the transforming enterprise or supply chain [7, 8].

However, even successful cases of proposed *Digital Transformation Frameworks,* for instance [8], struggle to formalize the operational levels of digital transformation. It seems that there is no clear distinction between (i) the digital transformation paths followed to digitalize an existing business process, and (ii) the engineering of a 'born-digital' business process based on newly available digital technologies.

2.2 Digital Technologies & Digital Transformation Frameworks

We have recently crossed the 10th anniversary of the Fourth Industrial Revolution, or Industry 4.0 era, which came alongside the introduction of new digital technologies such as "cyber-physical systems". These technologies enable us to connect the physical with the virtual world and bring forth tremendous (digital) opportunities as well as challenges for the design of next-generation production systems, specifically including their supply networks. The core principles of connectivity, virtualization, and data utilization [9] can take on various forms and provide numerous benefits across companies, supply networks, and even whole industries such as operations with higher visibility, transparency, predictability, and adaptability levels. Various innovative digital technologies are associated with this new industrial transformation, which is often wrongly reduced to the implementation of such technologies. As previously argued, it is believed that this "techno-centric" approach is posing a significant problem and it needs to be approached more strategically, using a combined approach of carefully reassessing the status quo of business processes and (digital) technologies, and then defining their future state more holistically.

2.2.1 Digital Technologies

Digital transformation efforts are often reduced to new digital technologies adoption, without including the pursuit of innovative and digitally-enabled business and operating models. Supporting this "techno-centric" approach, there is a large body of literature covering the characteristics and enabling factors of these new digital technologies. Prominent recent examples with significant citations include [10, 11, 12] among several others. While the various papers identify slightly different technologies and technology clusters associated with digitalization (and smartening) efforts, overall, these are consistent in what technologies are covered. A meta-analysis can extract 10 key digital technology clusters [13]:

(i) artificial intelligence, machine learning, and advanced simulation; (ii) cloud, fog, and edge computing; (iii) additive manufacturing, (iv) industrial internet-of-things and cyber-physical systems; (v) augmented reality, virtual reality, and digital twins; (vi) automation and robotics; (vii) cybersecurity; (viii) blockchain; (ix) smart sensor systems; and (x) 5G-networks.

All these technologies have received significant attention from industry, academia, and mainstream media over the last decade. Their business applications are evolving and the pressure for companies to at least have some active projects deploying some of these technologies is increasing. The tangible results however are sobering with many of these projects ending up with a 'successful' proof-of-concept, yet rarely transitioning into productive and value-adding use in enterprise-wide operations. Often termed the "pilot purgatory" [14], this challenge can partially be traced back to the lack of flexibility and awareness of the procedural requirements of the operations – and how they align with what advances the new digital technologies offer.

2.2.2 Digital Transformation Frameworks

Given the novelty and presence of new digital (and smart) manufacturing paradigms in trade publications, daily news, and overall public discourse it is not surprising that companies feel pressure to engage in activities targeting the adoption of digital technologies. To support this adoption, there are an increasing number of support systems available, ranging from maturity models [15] to dedicated decision support systems [16]. In the process, the manufacturing community also realized that support requirements for small and medium-sized enterprises differ from multinationals significantly [17]. Hence, dedicated models emerge, developed for various industries [18], company sizes [19], and application areas [20].

It has to be noted that most of the support systems are either targeting a generic, high-level, or a very defined process or technology. Rarely do these support systems address both comprehensively and allow for a critical assessment of current business processes and technological aspects at the same time. A reality that is very surprising to see in the industrial practice considering the academic efforts over the last decades of providing

enterprise architectures and frameworks for business-IT alignment, and information systems integration and/or interoperability [21].

3. Research and Practice Gaps of Current Digital Transformation Approaches

The ongoing divide between the domains of business process optimization/(re-)engineering and technology implementation has been extensively studied in the existing scientific literature provided by the Enterprise Architecture discipline under many *Business-IT Alignment Frameworks* [21]. Moreover, this disconnection between technological capabilities (i.e., 'how to do it') and the expected business value of their enablement (i.e., 'should a particular (combination of) technology cluster(s) be applied') is frequently observed in the industrial practice – and regularly causes issues in many digital transformation efforts.

While business processes excellence and technology clusters excellence are often achieved individually, the connection and understanding of their interdependencies seem to be lacking, mainly in industrial practice. Significant research in business processes innovation regularly refers to classic literature [22]. However, the majority of publications on "business processes engineering" focus on the need to reinvent the business processes and only addresses technology as a subordinate topic. A possible reason is the comparative novelty of digital transformation efforts – with the rapid growth within the last decade – and the majority of business process literature emerging before that threshold seems to be one important aspect of this disconnection.

Although there are multiple alternatives to map business processes, no dominant one exists [23] that is universally accepted as a standard. Neither is explicitly considering the employed resources for a process task. While the *Business Process Modelling Notations (BPMN)* are not explicitly limited to specific processes, only the *Supply Chain Operations Reference (SCOR) model* [24] explicitly aims to cover the business processes beyond the individual organization. However, despite its targeted application to supply chain management, it does not go beyond observing the employed resources if at all, even in its revised edition [25]. The more recent *Digital Capabilities Model (DCM)* [26] considers the technological requirements and maps these onto two levels of detail for the business processes model, which includes the inter-connectivity of sub-processes. However, the business processes are not detailed to task flows, so it is not clear whether it can serve to leverage the (digital) technologies to optimize the business processes. In addition, neither of the described models covers events or results provided by external roles such as roles outside direct managerial control. Except for entirely, vertically integrated enterprises (from primary resources to final consumer), business process tasks depend on external inputs from suppliers, distributors, or others. Yet, technologies that would facilitate the interaction of roles across these supply chain partners are not mapped.

Approaches comparable to *Value Stream Mapping* [27], which is a methodology enabling the reduction of waste in manufacturing settings, do not seem to exist for evaluating the quality of a given business process. Applications in process mining [28] focus on the three aspects of discovery, conformance, and enhancement but do not investigate the process flow in terms of roles in swim lanes, employed technology, or data source – essential components of any digital transformation project.

The more financially focused *Cost-to-Serve Methodology* derives the cost of a given business process to deliver customer value [29]. The underlying assumption is that business processes excellence drives down cost-to-serve but given the lack of a process excellence measure, it remains uncertain whether any improvements have reached a global cost optimum.

4. Multiple Use Cases as Evidence for Common Pitfalls of Business Processes and IT Integration

Given the dearth of available research, the analysis of multiple case studies, derived and anonymized from recent consulting engagements, supports and highlights the discovery of typical shortfalls in business processes re-engineering in its practical application today. Across differences regarding industries and/or

products, the case companies exhibit and report similar shortfalls across the board. The investigated domains in this paper to identify shortfalls transition from intra-organizational focus to inter-organizational, and include (i) decision engineering, (ii) intra-process quality, (iii) intra-company process alignment, (iv) inter-company process synchronization, and (v) process-technology alignment. To facilitate and enable a better comparison of the identified process shortfalls and control for some bias, only small and medium-sized enterprises in the manufacturing sector were included.

Table 1. Analyzed Case Studies

Use Case	**Core Product Segment**
Apparel	Fiber manufacturer
Home-appliance electronics	Handheld electronic devices
Medical supplies	Medical supplies and consumables
Elevator manufacturer	Elevators

- **Process & Customer Value Alignment:** Shortfalls in this domain result from a misalignment between customer value, which is achieved from decision-making and the executed business process. Colloquially, the process roles in such a shortfall are busy but not effective.
    - *Apparel* – a lot of data, no clarity of value generation. The case company had been collecting data from internal and external sources to understand the supply and demand patterns along its value chain. The results were synthesized in a digital twin of its value chain to prepare reports and dashboards. However, the key challenges were that the customer of such analysis was not involved in the design process, so the backwards-looking analysis was not able to provide value for forward-looking decision-making.
- **Process Completeness & RACI Consistency:** Even for cases in which a business process generates value; a shortfall may be the completeness and consistency of role assignment. The process only works from end-to-end because of exceptions, for instance, roles disregard the process to accomplish activities, or the activities are not recognized as dependent, and issues are resolved only during escalations.
    - *Home-appliance electronics* – lifecycle management decoupled from operations. For a home-appliance manufacturer, the business process had been mapped – also to a high degree ofgranularity following existing best practices – within functional boundaries. The challenge of missing inter-functional ("cross-silo") coordination was only noticed when manufacturing outsourcing initiatives stalled. The existing cross-functional gaps were no longer manageable within the organization and caused 'supplier-relationship' discord during new product introductions when sales plans could not align with supply plans because the bills-of-material were not released yet from engineering and the contract manufacturer did not receive the demand signal to prepare machine capacity. An issue that did not exist before when inter-personal relationships ensured that all functional departments were aware that new products were about to be released.
    - *Medical supplies* – a process making use of an advanced planning system does not address the required process coordination across functions. For a medical supplies manufacturer, the rollout of an advanced planning system in its supply chain function was expected to bring many improvements. When the expected improvements in supply responsiveness did not materialize, the root cause was eventually identified as ad-hoc plan reviews between the supply planners and the manufacturing lead. To improve overall plant performance, the plans

were reviewed, manually improved and then modified in the system. However, the shortfall in supply responsiveness was unattainable in the first place due to gaps in the system configuration.

- **Process Alignment:** In particular, companies with multiple facilities/plants/locations, but also in cases where more than one employee owns a process role, are susceptible to this shortfall. This shortfall may exist in multiple processes for the same plants (process boundaries).
    - *Medical supplies* – organizational alignment to execute processes diverges between plants. At a manufacturer of medical supplies, its processes across plants even for the same product categories and with supposedly templated IT infrastructure were unable to standardize their intra-plant business processes to enable top-down management control for increased supply chain agility. The reasons were that individual legal structures resulted in slightly different reporting lines and stakeholders' management, the templated IT infrastructure had slight differences in the order fulfilment for tax reasons (e.g., under which customer order status inventory was consumed), when activities like production declaration occurred and were entered, and multiple others. Each amalgamation of reasons proved intractable without introducing additional systems support.
- **Process Synchronization beyond the Silo:** The inability to manage external business process partners directly may lead to shortfalls in synchronizing across departmental functions (i.e., "silos") and across supply network partners.
    - *Medical supplies* – a business process requires activities to be carried out by suppliers or customers, but this will not be modelled in a traditional business process map. For a medical supplies manufacturer, interactions with customers (i.e., medical care providers) were challenging. The order fulfilment is required to input in terms of inventory levels under consignment at the customer and their consumption, as well as confirmation of proposed replenishments. The timing of the input delivery was questionable and data quality was uncertain. The resulting poor quality of replenishments was compensated by customer reviews of the orders which in turn resulted in changes in quantities and potential delays in approving the replenishments. While these operational issues are not unusual, the business process mapping did not indicate the extent of challenges and the repercussions in other activities in the business process.
- **Process & Technology Integration:** The quality of the business process mapping and the technology choice can fall short in optimizing the process by rethinking the required activities and the employed technology.
    - *Elevator manufacturing* – process redesign ignores technology leverage. For an elevator manufacturer, the business process innovation of the order fulfilment was approached with management buy-in and bottom-up involvement to address shortcomings in the existing process. The challenge occurred when, after the future business process was fixed, the hand-over to the IT function indicated that several technology solutions were ignored (e.g., increased supply chain visibility in the planning systems, push notifications instead of periodic checks for order updates, switch to a new project management system to replace the ageing one, etc.). Thus, the business process was optimized within the given organizational hierarchy and systems landscape, but the process was not optimized.

The five identified types of shortfalls for turning business processes into "digital operations", seem to be recurring. While not an exhaustive study of industry cases, two cases per shortfall type are provided. Despite the occasionally multiple shortfalls per use case, it should be noted that most of these companies have been able to grow in terms of revenue and/or profit for several years. This indicates that the shortfalls are not operational blockers. However, it must be noted that these shortfalls are observable at the end of multi-year digital transformation programs. While the analyses do not detail the extent of the shortfalls at the beginning

of these digitalization efforts it is safe to assume that the desire is to improve efficiency in the business operations (i.e., one or more business processes).

How these shortfalls are effectively bridged has not been exhaustively studied. However, in each industry case, the prevalence of manual intervention and the use of Microsoft Excel on the lower hierarchical levels is obvious. These companies have been visited regularly by one of the authors of this paper and the computer screens of the industry case employees rarely show integrated systems.

5. Discussion and Research Agenda

To support end-to-end supply networks' digitalization towards "digital operations", business processes and their IT must be well aligned. This implies as discussed that business processes and IT models of different supply network partners become integrated and/or made interoperable with each other. For such endeavour, three different approaches are commonly discussed in the literature [30]. The first approach focuses on the *IT alignment problem* and addresses it with *service-oriented architectures* to support information systems interoperability [31, 32], the second approach focuses on *business processes alignment* to make them executable across supply network partners by using *orchestration* or *choreography languages* [33], and the third approach focuses on *business-IT alignment methods* for detecting and correcting misalignments in a "two-way" [34]. These approaches have been well studied, nevertheless, these remain rather vague in the industry in terms of how to define and practice their "threefold alignment" [30] to sustain digital supply networks integration as business processes requirements and digital technologies evolve [35, 36].

Moreover, the fusion of business (processes) and IT strategies, their ideal alignment, in a Digital Economy (or Industry 4.0 era) seems to be inevitable. A phenomenon that nowadays practitioners and researchers refer to as "Digital Transformation", given the rising importance of digital technologies for the competitiveness of business processes. Therefore, companies and their supply networks need to aim beyond *business-IT alignment* in their business processes digitalization efforts and understand the differential value of digital technology for enhanced business processes performance, and how digital and hybrid business processes can leverage new digital capabilities such as visibility, transparency, predictability, and adaptability for the next-level of business processes performance and competitiveness [37].

Lastly, as the debate continues on how to successfully transform the operations of companies and their digital supply networks into high performance and competitive "digital operations", three indispensable research and practice lines emerge for the *Next Generation of Business-IT Alignment Frameworks,* also referred to as *Digital Transformation Frameworks* [38]: (i) How to improve the value derived from IT and digital technologies by using data analytics and machine learning solutions, (ii) How to enable agility by tapping into "cloud" scalability to increase or decrease IT resources as needed to meet the changing demand, and (iii) How to couple digital technologies with business strategies for the new "digital business strategies" required for a renewed Digital Economy.

6. Conclusions and Further Research

This paper has identified business processes as a potential resolution for the limited success in digital operations in companies and their supply networks. Scientific and grey literature, as well as multiple industry cases, indicate a research and practice gap in the successful digitalization of business operations; while the existing literature focuses mainly on the technological aspects of business processes digitalization efforts, the business processes (re-)engineering aspects appear to have been neglected in a much-needed business-IT alignment for successful digital transformations.

The two main limitations of this research paper are the selection of industrial use cases and the scope of the literature review. The industry cases may be a self-selected group, which has more process shortfalls than

the population of cases. Also, the examined cases may not be an exhaustive selection of all possible process shortfalls. An extended scope of literature review, possibly including more grey literature, may yield more results on the aspects of business process quality assessments.

Further research shall include a more detailed guideline to resolve the identified shortfalls, either individually or holistically. To do so, a detailed analysis of the enablers for continued operations despite the shortfalls can be expected to be helpful.

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8. Biographies

Dr. Andreas M. Radke is a Senior Executive Consultant at mSE Solutions since 2019 and is based in the Chicago office (since 2020). His work focuses on end-to-end supply chain digitalization, business process optimization, and digital supply network collaboration. He previously worked for Bayer AG (2018-2019) and other companies. He was CIRP Research Affiliate from 2012-2014 and received his Ph.D. from the Hong Kong University of Science & Technology in 2012. He was BVL Chairperson of the BVL Chapter Singapore from 2017 to 2020.

Dr. Thorsten Wuest is an Associate Professor of Smart Manufacturing at the Industrial and Management Systems Engineering Department of West Virginia University (since 2015). He has worked as a research scientist for BIBA – Bremer Institut für Produktion und Logistik GmbH in Bremen since 2009. He was named inaugural J. Wayne and Kathy Richards Faculty Fellow in Engineering in 2017.

Dr. David Romero is a Professor of Advanced Manufacturing at the Industrial Engineering Department of the Tecnológico de Monterrey (university). He is an Agenda Contributor at the World Economic Forum Council on “Shaping the Future of Advanced Manufacturing and Value Chains”, and a World Manufacturing Forum Ambassador. He serves at different editorial and scientific committees and advisory boards in academia, industry, and government in the disciplines of business and industrial engineering. Nowadays is focused on promoting the concepts of the “Operator 4.0” and “Digital Lean Manufacturing”; father of both terms.