Integrating blockchain technology in supply chain management – a process model with evidence from current implementation projects

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Abstract

In this paper, process models for the integration of information technologies in supply chains are evaluated and utilized for the development of a blockchain-specific model. Case studies are conducted to validate the model based on several implementation projects with the purpose to refine the model's phases and through focus group interviews and workshops. Even though most of the studied projects demonstrate a clear added value of their blockchain solutions, only few of them make it to the step of running a productive system and integrate the solution in their business processes. The outcome of this paper delivers a practice-oriented process model for integrating blockchain solutions in supply chains. It meets all developed requirements and is validated by interdisciplinary experts that consider a variety of use cases and supply chain application areas.

Keywords: Distributed Ledger Technology, Case Study, Enterprise Networks, Technology Integration

1. Introduction

In enterprise networks, the levels of both cooperation and competition are increasing, mainly due to globalization. This development demands for new co-opetition approaches to achieve the next level of innovation (Chen et al., 2020). Emerging technologies, such as blockchain technology, address this development and are piloted in various industries to establish trustful and traceable relations between potentially untrusted parties (Große et al., 2021). Already in 2015 and 2016, with the emergence of blockchain-based smart contracts, the potential of blockchain technology for enterprises was described by (Swanson, 2015) and (Radziwill, 2018) mainly as an enabler of secured and decentralized data exchange as well as track and trace solutions. Also during this time, the first proof of concepts (PoC's) were developed by first-movers, namely IBM, Maersk, Walmart, Oracle, Carrefour, and many more, covering several industries (Grover et al., 2019; O'Brien, 2019). Even though the developed concepts demonstrated feasibility and significant potentials of the technology, only few projects successfully introduced productive systems. Thus, 87% of 447 projects investigated in 2018 and 80% investigated in 2020 remain in their proof-of-concept or pilot-stages (Gartner, 2022; Pai et al., 2018). Main obstacles for these circumstances are seen in clearly determining the technology's business value (Önder & Treiblmaier, 2018; Schwarzer et al., 2022; Varriale et al., 2020), as wells as in missing procedures to integrate the solution into supply chain processes (Gonczol et al., 2020; Gürpinar et al., 2020; Panarello et al., 2018; Reyna et al., 2018). Therefore, the two described research gaps will be addressed in this paper, and the following research question will be utilized:

What phases and steps should be considered by enterprises when integrating blockchain technology in supply chains to accomplish a productive and profitable system?

To answer this question, first a theoretical background on technology integration, blockchain characteristics and its utilization in supply chain management is presented. A focus is given on the challenges of utilizing blockchain solutions in supply chains. In section three, the systematic literature review methodology to identify relevant models and requirements is introduced. Here, blockchain-specific requirements are aggregated and used to evaluate state of the art integration models. Also in this section, a videos analysis of blockchain practitioners is described to add practical insights to the already developed requirements. As a third component, case studies are described that finally apply and validate the newly composed integration model based on current blockchain projects. In section four, the model is described in detail and discussed with evidence from the experts. Section five concludes the work and sheds light on limitations and future research opportunities.

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2. Theoretical Background

2.1 Blockchain Technology Characteristics and Integration

Blockchain technology can be seen as a subset of different distributed ledger technologies (DLT) that describe decentralized, or rather distributed IT infrastructures. In these infrastructures, accounts are no longer managed centrally by an instance, but in a distributed peer-to-peer (P2P) network (Morabito, 2017). Blockchain technology uses cryptographic mechanisms to encrypt data sent to the network and utilizes “blocks” to store transactions chronologically “chained” together. This way, the data is distributed among the network participants represented by nodes that therefore possess the same data insights (Beck et al., 2017). Moreover, different blockchain solutions can be categorized into public ones that grant complete data transparency and are applied, especially in cryptocurrencies. Other than that, private and consortium blockchain solutions have permission access-, read- and write authorization for either a single network member or a consortium of members. In current blockchain projects, private and consortium variants are used more frequently.

This paper theorizes on the integration of blockchain solutions by utilizing information system (IS) research. Information systems rely on an interplay of tools, hardware, software, and people to work together and collectively process and redistribute information to appropriate parties (Autry et al., 2010; Hazen et al., 2012). In this context, blockchain technology is deemed capable to combine the before mentioned utilities to form one all-encompassing information system (Berdik et al., 2021; Gürpinar, Austerjost, et al., 2022). Types of IS integration can be seen in data integration, functional integration and process integration, of which the third one gets shaped on an organizational level by social enterprise and social customer relationship management approaches (Norshidah et al., 2013). The third type, the integration into an organization and its business processes, is being focused on in this paper. In this context, the diffusion of emerging technologies in organizations is described with three dominant phases: the initiation, adoption, and routinization phase. The routinization phase describes the actual use of a productive system, which will be the target of the developed integration approach.

2.2 Blockchain Technology in Supply Chain Management

Supply Chain Management (SCM) aims to coordinate, optimize, and establish error- and failure-free supply chains, ranging from raw material extraction to the finished product while considering economic aspects (Giese et al., 2016). The supply chain and its partners are linked by the flow of materials, information, and finance (Beckmann, 2012). However, at the current time, the financial flow is only connected to a limited extent and, as a result, is not synchronized with the service provision process (Gürpinar, Große, et al., 2022).

Blockchain solutions claim to address this issue and already claim the logistics and supply chain field as one of its most viable application areas for blockchain projects (Erol et al., 2021). Mainly private and consortium blockchain solutions fulfill SCM requirements. The number of smart devices in the Internet of Things (IoT) increases significantly and demands for trusted, transparent, and cost-efficient IT infrastructures (Große et al., 2021; Kshetri, 2018). Blockchain solutions are used to create the prerequisite of gapless documentation of transactions and data. At the same time, all relevant supply chain partners can get access to track the production progress or the transportation process of goods (Brody, 2017; Giese et al., 2016). Blockchains also help to trace back information and therefore in delivering a proof of origin for products that can help to stick to sustainability goals and ensure corporate social responsibility (Zhang et al., 2020). Furthermore, mutual trust between the network partners is achieved through immutably stored and distributed data. Accordingly, expenses for central authorities like banks, certification, or assurance service providers are reduced significantly (Kshetri, 2018). Finally, through blockchain-based smart contracts, manual, paper-driven processes can be automatized and therefore reduce the possibility of fraud or error-proneness and speed up processing times.

Taking the above levels into account, the integration of blockchain solutions poses various challenges that can be categorized by means of the human-technology-organization (MTO) approach that has been expanded by Henke et al. to include the area of information (I) (Henke et al., 2020; Karltun et al., 2017) and will be published in a subsequent paper. The focus of this paper is on the organizational dimension that affects the challenging integration of blockchain solutions in supply chain processes of the various stakeholders while considering profitability.

3. Methodological Approach

As only limited research has been conducted on the integration procedures of blockchain technology in supply chain management, in this paper an explorative research design is required and conducted by means of the *Grounded Theory*. Grounded Theory characterizes an explorative, qualitative research design that is comprised of a collection of systematic but flexible guidelines, and practices applied for qualitative data collection and analysis (Holstein, 2013). (Holstein, 2013) emphasizes the receptiveness towards observations through expert interviews as a research method, leading to data being the starting point of the research. However, Grounded Theory does not aim to provide complete individual statements as evidence. Instead, the aim is to take a theoretical analysis of observable practices to a higher level while maintaining a clear link to the data (e.g. literature) (Mills et al., 2006).

Starting from these insights, a research process is developed to answer the research question raised in section 1. The foundation of the paper is developed through a systematic literature review searching through blockchain and connected literature fields. On that basis, blockchain-specific requirements are developed and used to evaluate already existing integration approaches in the following state of the art section. Then, the literature work and especially its requirements are supplemented by a blockchain practitioner video analysis. Finally, a case study consisting of focus group interviews and workshops is conducted. While the interviews are considered as a valuable method for collecting qualitative data and – in case of the grounded theory start with open questions that later interviews lead to in-depth discussions – the workshops are utilized as validation method (Holstein, 2013; Lingard et al., 2008).

3.1 Literature Research

To find integration models used for technologies similar to blockchain, a systematic literature search according to (Durach et al., 2017; van Wee & Banister, 2016) is conducted. The chosen method was based on the rationale that systematic approaches promote increased transparency and facilitate discussions regarding the selection process (Easterby-Smith et al., 2018). To start the process, the scientific databases Scopus, ACM, Web of Science, Science Direct, Google Scholar, and Springer Link are utilized to identify a number of 1033 relevant articles by searching for blockchain and other emerging technology's integration, implementation, and process models. The search includes articles that explicitly deal with blockchain technology, but also with cloud- or other disruptive, and industry 4.0 (I4.0) information technologies.

As exclusion criteria, articles with a publishing date before 2004, non-English or German, and those articles counting to grey literature are neglected. The result shows an article collection consisting of 83 articles that present integration models for blockchain, cloud, other disruptive- or I4.0 information technologies, of which eight explicit models are selected as best practices based on orientation and relevance.

As a next step, requirements raised by blockchain technology in supply chain management are extracted from those articles with an according focus. The requirements were identified by the requirements engineering method following Pohl and Rupp. According to them, the first collection of requirements is unsorted and bundled (Pohl & Rupp, 2015). Therefore, two tables are created for separating those requirements that are technology-centric and those that are generally placed on integration models. As requested by Rupp, the included requirements are classified according to basic, performance, and enthusiasm factors and aggregated in the next step (Pohl & Rupp, 2015). As a result, figure 1 shows the already aggregated seven requirements for blockchain-specific integration models.

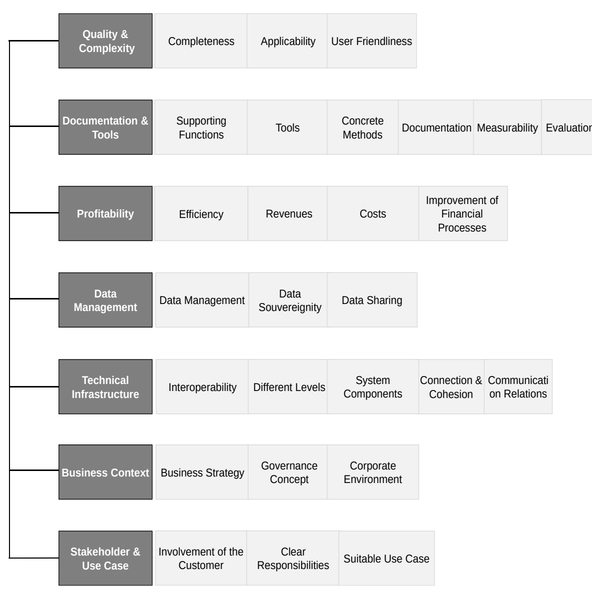

Figure 1. Requirements for a blockchain integration model

Based on the identified requirements, the eight integration models are evaluated separately. The evaluation of the models shows that none of the models, fulfills all the developed requirements. While previous blockchain-centric work (Gürpinar et al., 2020) already covers an essential portion, still the developed integration model lacks practical validation and sufficient documentation throughout all steps, while only little guidance is given on the decision of particular use cases. The model of (Fill & Meier, 2020) lacks in business context and entirely neglects the consideration of profitability. The same weakness counts for the model of (Pedersen et al., 2019), while (Bender et al., 2019) neglect technical aspects in contrast to that. The other half of the selected models focus on industry 4.0. technologies that therefore have less focus on stakeholder networks and again neglect profitability considerations.

3.2 Video Analysis

To build upon the literature-based findings above, practical insights are added through a video analysis of blockchain experts. Previous studies have found that video platforms deliver valuable insights for research through recorded expert interviews, panel discussions, or presentations by relevant practitioners (Dessart & Pitardi, 2019; Hollebeek, 2019; Karpen et al., 2012; Ming Tan & Saraniemi).

The video platform YouTube was selected as the primary choice due to its widespread usage, and the search strings "blockchain integration" and "blockchain supply chain management" were utilized to identify videos that provide valuable insights on the topic at hand. From more than 100 videos, 32 videos are selected based on their titles and the following inclusion criteria: (1) videos broadcast in English language, (2) videos focusing on critical and necessary steps to consider when integrating blockchain solutions, (3) well-known and internationally renowned institutions are given priority. The remining videos are assessed by two separate experts and by means of the 5-point Global Quality Score (GQS). It considers the authenticity, quality, utility, as well as the scope of the videos and is an established method in qualitative research (Culha et al., 2020; Li et al., 2019; Toprak & Tokat, 2021). Based on that, 18 videos were selected for presentation in this dataset. Finally, four videos with the highest score are featured in the following list, shedding practical insights on the requirements to integrate blockchain technology in supply chain management:

- Current blockchain projects keep stuck in the process between proof of concept and full-scale deployment. Enterprises need support for their organizational transformation (video #16).
- Blockchain solutions enable their true power of transformation only when integrated with IoT devices and in combination with other technologies that need to be considered in an integrative approach (video #16).
- Blockchain participants must come to a consensus on how to adapt the information flow and to a decision on what exact data to be shared among them (video #3).
- When integrating a blockchain solution, objectives must be clear, a comparison of the status before and after has to be drawn, and a decision needs to be taken whether or not it is a blockchain solution that solves the problems in the best possible way (video #1).
- In order to get the best profit out of blockchain usage, collaboration is needed among the Stakeholders. Aligning the stakeholders' interests within the ecosystem is the hardest task right now in current blockchain scenarios, especially in the case of multinational enterprises and with consideration of government tasks (video #18).

3.3 Case Studies

To validate the findings and challenge developed versions of the integration model with the evidence of current blockchain projects, case studies are carried out in two rounds of data collection (Patton, 2009). Given the early stage of blockchain research, a qualitative approach adds validity to theoretical findings and constructs while particularly conducting case studies helps to identify empirical regularities across various contemporary cases (Tsang, 2013). Overall, the case study research took place over half a year, with data analysis and writing continuing for half a year. In contrast to the video analysis, it focuses on currently ongoing development projects with several experts from different disciplines. In round 1, five blockchain pilot projects in the field of supply chain management are investigated with a series of focus group interviews. The method is used to acquire data directly from experts involved in the projects and discuss at least three different perspectives for each case. All experts possess profound knowledge of unique experiences arising from their actions, responsibilities, and obligations as members of a particular project team (Calder, 1977). Expert sampling is used, and participants are chosen based on their professional experience, knowledge, and affiliation. All experts received an invitation email with a complete summary of the study and a brief explanation of the approach. In the interviews, the experts are approached in groups of three to four people and interviewed with respect to their blockchain projects (see Tab1). In round 2, two workshops are conducted to generalize the case-specific outcomes of the interviews and check the external and internal validity in a larger group of experts (Baran et al., 2014). The first one was conducted with seven external blockchain experts from companies not involved in the focus group interviews. The second one was conducted with six experts as a mixed selection of the prior focus group participants (see Tab1). In the second round, professionals who were either working on a blockchain project or conducting in-depth research on blockchain solutions were selected. The discussions in all rounds had a duration of approximately 90 minutes. The data collection methods employed included verbal questioning, as well as observation and documentation of the participants' words and actions (Hollweck, 2016). The interview questions were embedded into a semi-structured interview guideline and developed in accordance to the phases of the integration model (see the guideline and workshop concept in this dataset).

Table 1. Data collection round 1

Type	Case	Industry	Roles	#
Focus Group	Customs information sharing	Automotive	Product Owner, Deputy Product Owner, Specialist	FG1
Focus Group	Tracking & tracing of dangerous goods	Logistics	Product Owner, Specialist, Specialist	FG2
Focus Group	Electronic pallet exchange	Logistics	Project Manager, Lead Developer, Developer	FG3
Focus Group	Digital records of maintenance services	Maintenance	Project Manager, Specialist, Specialist	FG4
Focus Group	Decentralized data marketplaces	IT	IT Manager, Project Manager, Finance Specialist	FG5

Table 2: Data collection round 2

Type	Industry	Roles	#
Work-shop	Banking, Logistics, Energy, Telecom, Automotive, Consulting	Supply Chain Finance Expert, IT Researcher, Project Manager, Engineer, Lead Quality Manager, IT-Consultant	WS1
Work-shop	Automotive, Logistics, Maintenance, IT	Multiple roles mixed from the prior focus group interviews	WS2

In all rounds at least two researchers were present in the data collection events to support the interviewing researcher in calibrating the research instruments. Both the interviews and workshops were recorded, while one of the researchers took notes during the discussions. Right after the events, all researchers wrote additional memos to capture further thoughts and compiled a summary of the findings of each interview. The summary was then submitted to the respective expert to avoid any potential misunderstandings. Extra follow-up talks were scheduled with the experts to explain any outstanding concerns. In the further analysis process, the thematic coding approach by (Gibbs, 2007) was utilized and the phases of the integration model were utilized as categories. Coding quality was endured by peer-debriefings with blockchain researchers. During the analysis, groups exhibiting different expressions or trends were investigated with a higher focus, and case conclusions were extracted for each case and category. The categories were analyzed by combining the results of several groups with comparable characteristics.

4. Findings and Discussion

The final model for integrating blockchain technology in supply chains is presented in Figure 2, based on the theoretical findings, and refined through case studies. The most important findings for each process step are enclosed and refer to both data collection rounds by using the markers FG-X and WS-X. The model phases 2-4, as well as 4-6 proceed iteratively throughout the entire project. A focus is given on the decision phase of the integration process.

Preliminary Evaluation: The decision phase of the integration model starts with the preliminary evaluation. Here, it is necessary for enterprises to first get familiar with technical and conceptual fundamentals of blockchain technology in order to understand its strengths and weaknesses (Fill & Meier, 2020). In this context, it can be noted that the technology understanding process peaks in the beginning but should be continued throughout the whole project (FG1). What cannot be neglected here are the technical functionalities blockchains are based on. Especially executives should develop a basic understanding of P2P-networks, cryptography, and consensus mechanisms (FG2). Furthermore, blockchain application areas, advantages and disadvantages over other technologies and differences between private and public blockchain frameworks should be clearly understood (FG3). Ideally, at this point, best practice examples should be studied from similar industries or application areas (FG4,5).

In correlation to the first step, enterprises should set a goal for their blockchain plans from the early beginning and therefore determine integration needs (Gürpinar et al., 2020; Peukert et al., 2020). In this context, it is important to have a closer look at the problem situation to be solved and come to an agreement on whether changes in the IT infrastructure are necessary (FG1,3). Also, at this point, enterprises should consider whether centralized or decentralized approaches make sense for their particular problem situation (Große et al., 2020). Here it can be helpful to utilize additional blockchain guidelines to be sure about a good fit and make sure several untrusted parties are involved in the use case (FG2).

In the next step, it is necessary to determine and structure a blockchain use case and stakeholder network (Gürpinar et al., 2020; Peukert et al., 2020). In this context, enterprises should already know where they have inefficiencies and what exactly to improve. Also, enterprises should understand different blockchain use cases to leverage synergies and activate all involved enterprise functions and departments (FG1). At this point of the process, governance matters should be discussed in the project team and comprised of the most important technical and IT security related requirements, management and organizational, and legal requirements (FG2,WS1). As setting up the stakeholder network is one of the biggest challenges of current blockchain projects, communicating project ideas in a larger consortium from the early beginning is necessary to build up the network and decide on roles and responsibilities (WS1).

In the fourth sub-step of the preliminary evaluation, potentials and challenges of the concrete use case should be identified to be able to carry out an initial evaluation of the project's meaningfulness (Nguyen Ngoc Son, 2020). In this context, the use case set-up needs to be analyzed in detail. A focus can be given on business-related aspects at this point (FG1). An outcome can be a structured catalog (FG3) that already contains monetary aspects (FG4). It is important to note that many projects try to monetize their benefits already at this point but fail due to unknown process dependencies (FG5). The connected evaluation step should deliver a first impression for the project consortium to decide whether or not it makes sense to get deeper into the project setup (Peukert et al., 2020). In this context, enterprises should focus on their overall project goals once again and weigh up the potentials and challenges through that lens. An outcome can be a SWOT matrix that gives a high-level orientation (FG4).

Analysis: The second step of the decision phase consists of an analysis of the actual business processes affected by the chosen use case. With this step, the iterative process of the model starts that allows enterprises to gradually increase the scope of their blockchain project to further enterprise functions and processes. Besides the specification of the roles of external project members i.e. supply chain partners, also internal enterprise functions and departments of the own organization need to be activated (Düdder et al., 2021), (FG1). At this step, ideally, the initial evaluation of meaningfulness is extended to also cover requirements of involved external and internal entities. This way, a distinction can be made between partners that would use the blockchain solution as a product to be incorporated in their business model, or need to be incentivized for participation (FG3,4,WS2). The analysis of concrete business processes provides the basis for the blockchain concept of the respective use case. Here, the recording of processes can take place via modeling languages or notations like the "unified modeling language" (UML) or the "business process model notation" (BPMN). Ideally, the business processes are described in a detailed and sufficiently accurate way to offer starting points for their optimization. For this reason it makes sense to cut out and start with a smaller section of a process that delivers sufficient details (FG1,2,3,WS2). In the third step of the analysis phase, the information flow of the visualized business processes deserves closer investigation, especially in its external inter-organizational form. Most importantly within this step, the current data management concepts are analyzed to determine which partners currently have access to what kind of data and how this data is stored (Gürpinar et al., 2020). Also, governance and compliance aspects should be considered here, including data-related regulations from the government as well as those from the management level (FG1,WS1). At current projects especially restrictions emerging from the General Data Protection Regulation (GDPR) concerns project managers (FG5,WS2).

In the next step, already existing information systems and devices are recorded and listed to depict the IT status and level of digitalization of the consortium (Gürpinar et al., 2020; Qu et al., 2018). At this step, the interoperability of different systems needs to be investigated. Also, here, it is important to consider where data originates from, what hardware devices are involved in the recording process and how it is assured that data is not tampered (FG2,3). As a last step of the analysis phase, the potentials and challenges of the use case should be adapted and concretized. This way, the meaningful continuation of the project can be assured. Again, the identified criteria can be gathered in catalogs, to be used as a basis of the profitability analysis at the end of the decision phase (FG5,WS1,WS2).

Business Concept: The third step of the decision phase consists of the blockchain - based business concept that is developed based on the previous process analysis. It is embedded in the iterative process of the model i.e. concepts for particular business processes can be developed incrementally. Based on the visualized current business processes, in this step, first, the goals and targets of the blockchain -based concept are defined, before the processes are adapted accordingly. For the adaption, the visualized processes from step 2b can be used. As inter-company processes are involved, again governance aspects (decision rights and accountability, roles, and responsibilities) have to be considered (WS1). While implementing the blockchain layer into the visualized processes, in this step it must be clarified which systems are connected to the blockchain solution, which information needs to be extracted and where this information is stored in the blockchain environment (FG1,2,3). At this point, it is important to already plan which information needs to be stored on chain and which data is fine to be kept off chain (WS1). Based on the maturing business concept, it becomes possible to derive more concrete process - based benefits from the previously identified broader factors. In this context, increased revenues, as well as process, resource, and expense optimization opportunities can be estimated together with respective functional experts (FG1,2,3).

Technical Concept: In the next phase of the integration model, the technical concept is developed as a supplement of the business concept and in order to establish a first pilot to demonstrate feasibility. The start of this phase is highly depended on the outcome of the prior benefit analysis, as it has to be decided whether or not to start involving technical staff or hire external service providers. To develop the integration plan, final decisions have to be made regarding the blockchain framework and respective hardware components (e.g., selection of proper IoT devices) that collect the data and communicate with the blockchain (Pedersen *et al.* 2019, p. 102). At this point, it is important to determine how devices communicate with the blockchain, as they can be connected via light nodes, or need a gateway to write on the blockchain (FG1). Dependent on the chosen blockchain framework, also the consensus mechanisms will be determined and play a crucial role in terms of the technical governance, influencing the method of collaborative work among the blockchain partners (WS2). After deciding on a plan to set-up the blockchain framework, the data model from phase 3b needs to be finalized to demonstrate all relevant data streams (WS2). Finally, the design of a blockchain prototype is to be set -up before starting into further incremental software development. Prototyping a single crucial part of the system serves as a best practice for the rest of the increments and helps internal and external parties to get to a better technical and unified understanding (WS2). Importantly, interfaces to internal and external systems need to be planned ahead and included in the cost calculations of the next step. In this phase, again, it is necessary to communicate with all network participants and finalize the infrastructure concept determining which participants run full nodes and which systems or devise will be connected via light nodes (WS2).

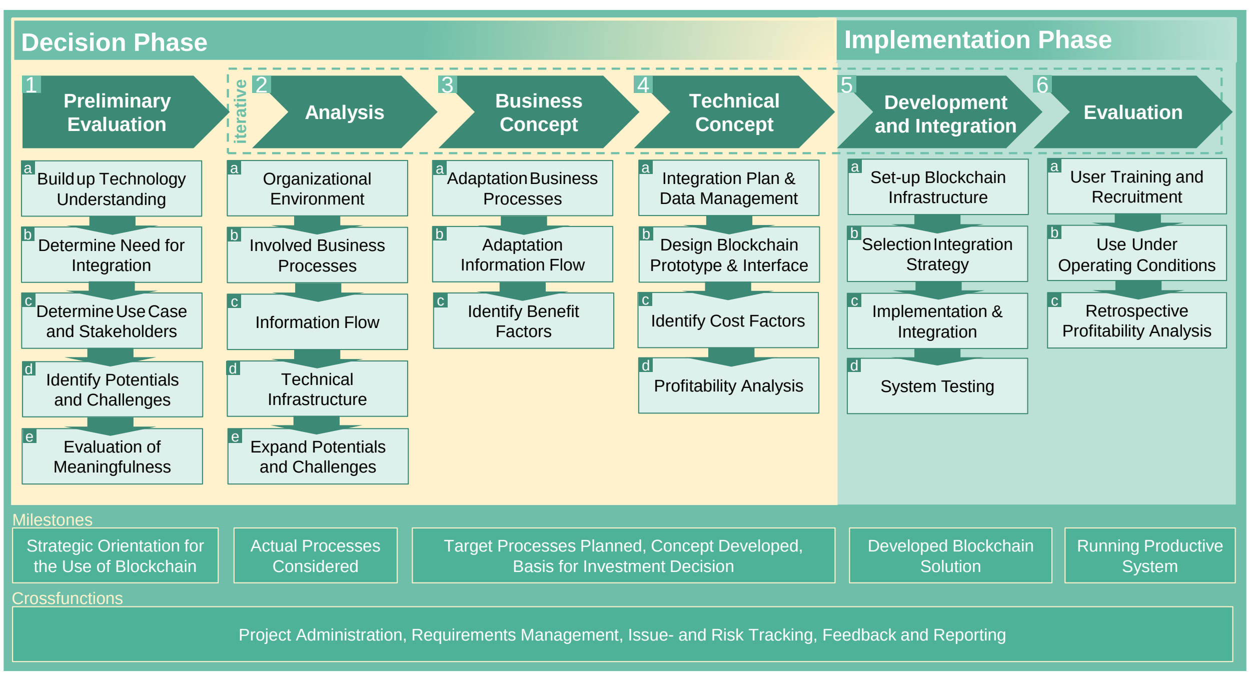

Figure 2. blockchain integration model

As a counterpart to the already identified benefit factors, the costs are highly dependent to the technical framework in place. This is why they are determined after finalizing the infrastructure concept. The factors can be clustered into costs that occur during initialization, prototyping, and costs for maintaining the running blockchain system, which also includes staff trainings (FG1,2,3). Finally, as a last step of the decision phase, a profitability analysis can be conducted by balancing the previously identified benefit and cost factors. At this step, usually several qualitative benefit factors (like trust or transparency) need to be considered that could not be quantified during the benefits analysis (FG1,2,3). For this reason, it can make sense to artificially quantify them with tools like the utility analysis and consider respective uncertainties and risks in further calculations (FG4,5).

After deciding on a business and technical concept, in the final implementation phase, the development and integration as well as evaluation of the blockchain solutions take place and will be focused on in a subsequent paper.

5. Conclusion and Future Research

In response to the identified research gap of *structured approaches for integrating blockchain technology in supply chain management*, a process model was developed. The model consists of a decision phase and an implementation phase, aiming to guide enterprises from their initial contact with blockchain technology to the stage of operating a productive system integrated in supply chain processes. The integration process encompasses four levels: shop floor, system, enterprise, and value chain, which are considered throughout the entire process. The developed model is comprised of six main steps, rounded off by milestones each and consisting of 24 sub steps in total. Each sub-step thereby is described and supplemented by expert opinions on the most relevant aspects to be considered and further insights from current blockchain implementation projects. In response to the identified research gap regarding measurement of profitability in blockchain solutions, a framework consisting of seven sub-steps has been designed to rank tasks in a specific order and at appropriate points in time. It is demonstrated how to derive a preliminary evaluation first and build a more comprehensive profitability analysis on top of it. This way, enterprises are enabled to make their investment decisions before hiring or training staff for the actual implementation. Finally, an ex-ante evaluation takes into account the productive system for optimization purposes.

The developed integration model demonstrates its applicability along five different cases of the SCM domain and was successfully validated by blockchain experts. It fulfills all developed literature-based requirements, especially by adding empirical findings to mostly literature-based previous works. It addresses the problem situations presented in a video analysis, as it (1) guides enterprises to achieve a full-scale deployment, (2) considers different use cases with blockchain as a backbone for other IoT technologies, (3) possess a separate section for the adaption of information flows, (4) delivers profitability assessment steps to decide whether or not blockchain is the right choice for the respective use case, and (5) offers particular phases to consider different stakeholders and their organizational environments.

Nevertheless, the final model was not yet used as a basis for the decision and implementation processes of a newly beginning project. Accompanying a project from the beginning to its successful integration would increase the model's validity. Another limitation of the research lies in its regional scope, as mostly European and particularly German project have been observed. It would be interesting to also record more regional differences in integration approaches. Finally, the study offers several starting points for further studies that can challenge the model in specific use cases or equip the developed phases with micro foundation and explicit methods to elaborate on them in more detail.

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