Stakeholder Involvement Added Value Indicators in IT Systems Design for Industry 4.0 Digital Innovation Hubs

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Abstract This chapter is addressing the creation of added value by means of concurrent engineering in the early stages of IT systems design for Industry 4.0 enterprises in the context of Digital Innovation Hubs. The recent phenomenon of Digital Innovation Hubs poses new opportunities and threats in introducing advanced collaborative IT services co-developed by a number of complementary subjects, such as ISVs, infrastructure providers, consulting firms, research entities and others. Unlike other business networks or chambers of commerce, Digital Innovation Hubs place research entities at the core of innovation ecosystems. Such approach may result in transversal involvement of external stakeholders in research and development IT projects. While consequent opportunities are many, so are the threats and uncertainties. This article analyses related pros and cons based on research results published thus far and selected ongoing use cases. Furthermore, this article proposes new investment risk factors resulting from broadening the pool of IT system design stakeholders.

Keywords Industry 4.0 · Concurrent engineering · Digital innovation hub

1 Introduction

The Information System (IS) industry has to provide added value, or value proposition, desired by their customers in order to spur profits. This article is addressing the creation of added value by means of external stakeholder engagement and concurrent engineering in the early stages of IT systems design for 4.0 (Industry/Logistics) enterprises in the context of Digital Innovation Hubs. The recent phenomenon of Digital Innovation Hubs poses new opportunities and threats in introducing advanced

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P. Golinska-Dawson et al. (eds.), *Smart and Sustainable Supply Chain and Logistics – Trends, Challenges, Methods and Best Practices*, EcoProduction,
https://doi.org/10.1007/978-3-030-61947-3_7

collaborative IT services co-developed by a number of complementary subjects, such as ISVs, infrastructure providers, consulting firms, research entities and others. Unlike other business networks or chambers of commerce, Digital Innovation Hubs place research entities at the core of innovation ecosystems. Such approach may result in transversal involvement of external stakeholders in research and development IT projects. While consequent opportunities are many, so are the threats and uncertainties. This article analyses related pros and cons based on research results published thus far and selected ongoing use cases. Furthermore, this article proposes new investment risk factors resulting from broadening the pool of IT system design stakeholders.

The goal of this chapter is to verify by means of qualitative comparison analysis if there is a need to conduct action research in the field of value-driven/concurrent engineering, which would enable comparing and balancing the benefits and risks resulting from an early inclusion of external entities (members of I4.0 manufacturing companies' ecosystems) in the early stages of information system (IS) design.

While the vast majority of research focuses on applied IT system design done by corporates with clear predefined targets, this article analyses the tools and approaches research organizations take at the early stages, up to Technology Readiness Level 3 (TRL3), of technology integration and information system development. Unlike corporates, whose main objectives are to grow profits and cut costs, research organizations focus on expanding the boundaries of knowledge. On this account the perspective of research entities on concurrent engineering may differ significantly from the corporate or industrial perspectives and analysing this phenomenon shall bring to light new, unobvious values, underrated in corporate-driven ecosystems. Also, this same analysis may initiate taking a broader perspective on the value creation issue—the one of R&D investment risk mitigating tools, potentially useful for both corporate and academic research environments.

The highlights of the chapter are:

– analysis of information system development perceived added values shared by academic and business ecosystems,
– comparison of closed and open innovation paradigms
– proposition of new unobvious R&D investment risk factors
– subjective prioritization of R&D investment risk factors
– analysis of investment risk management tools.

The main contribution is the development of a collaborative DIH based service development approach which enables an intentional management of uncertainty as a critical R&D investment risk factor.

The chapter is organized as follows: first, in Sect. 2 academic vs industrial values and indicators are contrasted, thence presenting the different approaches to R&D and IS design. Section 3 defines the problem—what is the unobvious added value of collaborative IS/service design and how can the key factors be managed in industrial settings. The following Sect. 4 proposes a DIH based approach to managing IS design uncertainty by providing a subjective ranking of unobvious values shared by industry and academia, listing their success factors and assessing the impact of the digital innovation hubs approach on these factors. Conclusions of the final Sect. 5 are followed by further research recommendations.

2 Literature Background

Literature hardly addresses the fairly new phenomenon of Digital Innovation Hubs in view of value-driven Information System (IS) design. Although it has not yet been thoroughly examined, a number of related studies have been published, mainly addressing the corporate perspective on IS design in closed environments, which can serve as a reference platform for our analysis.

On the one hand, closed IS design environments have been thoroughly studied—by focusing on R&D investment risk, Bahli and Rivard (2005) list the factors having biggest impact on the efficiency and results of outsourced IS design. On the other hand, design environments following the open innovation paradigm focus on the methods rather than efficiency and economic results. Some analyse the very concepts of design, showing how new, collaborative methods can be co-created either by in-house employees or by involving external professionals. For this purpose novel event formulas are tested, such as ideation contests or codesign workshops. IS design, being one of many areas in such studies, appears interchangeably with service design. Consequently, these analyses and the underlying recommendations referring to team-building, market exploration or process management refer to codesign as the primary subject, while IS design plays the role of a reference point rather than the primary subject. Although references to IS design across codesign studies are rather mild, selected conclusions can be quite relevant and trend sensitive. Like in any codesign endeavour, also in IS design, the general migration from granting a sole expert individual the full responsibility for design outcomes to enabling customers or users join IS design teams and play the roles of experts of their experiences (Visser et al. 2005).

The process of involving external stakeholders in service design has been divided into stages. Its application from stages from TRL1 to TRL3 as ideation has been analysed, querying whether or not such approach can benefit an organization's innovation outcomes. From the process perspective two approaches to research have been proposed (Edvardsson et al. 2005), as a "category of market offerings" or a "perspective on value creation." Little attention has been paid however, to economic benefits of the novel process, resulting in limited usability of these studies in real-world decision-making, including added value or investment risk measurements. The existing research is based on a service centred approach, assuming a logic that is always uniquely and phenomenologically determined by the beneficiary (Vargo and Lusch 2016, p. 8).

In terms of types of stakeholder involved, the present research is based on B2B relations, rather than science-to-business or business-to-customer, which results in the neglecting of the two latter types. Moreover, the analysed cases most often focus on local, near proximity entities, leaving the broader context of international markets aside (Gemser and Perks 2015). Whereas, the ability to consciously involve specific extreme customers or partners who have particular need ahead of market with highly estimated expectations (von Hippel 1986) can be very beneficial for IS design and innovation (Mahr et al. 2014). One of repeated hypotheses across literature, is that by involving customers a company can become more resilient to investment risk by avoiding the problem of user needs being sticky, difficult to transfer, and articulate (von Hippel 2001; Witell et al. 2011).

It is worth mentioning that already the traditional design studies, unlike IS approaches, implied that participatory approach required the "exchange between people who experience products, interfaces, systems and spaces and people who design for experiencing" (Sanders et al. 1999).

The lack of proper participatory IS design tools has also been covered from public services perspective, such as medical software for patients and caregivers. While it is evident that IS shall support and not hinder the experiences of caregivers and patients, little or no tools actually enable gathering requirements or insights from these target groups. The consequent misalignment of medical software results in highly qualified staff spending more of their time with the computer screen rather than with the patient. In this case the key factor or added value resulting from involving patients and users in the IS design would be the shortening of time doctors, physicians and other caregivers must spent at their computers. Based on specific medical workflows, involving all key stakeholders, concrete steps and related insights are introduced, playing the role of a showcase of tools for healthcare innovation projects (Vollmer 2019). Similarly to industrial contexts, the medical software fails to take a holistic approach to the addressed process, to embrace the off-screen experiences and finally to deliver tools that solve existing real-life problems without causing new ones. The present studies of specific use cases in medical area may bridge the conceptual gap between the industrial and academic contexts. Some of these cases have been introduced as role models for novel methodologies, such as EVOKE (Early Value Oriented design exploration with Knowledge maturity), meant to facilitate the selection of the newly appearing IS design possibilities with a focus on added value related information.

Engineers' tendency to avoid redesign during development, especially at IS component level, is yet another added value hindrance addressed in recent studies. All too often IS developers go back to initial setting of value, agreed for the IS with the product owner early in the project and before external, non-technical stakeholders were even introduced to the planning. This phenomenon may give grounds to either earlier involvement of the user or to extending the IS concept definition phase. Either way, study shows that selection of the right moment when users' needs are introduced might be critical for IS development. Similarly, the knowledge […] where user needs originate and mature becomes critical to understand which sub-system performances have to be sacrificed to optimize the overall system behaviour. This makes systems engineers to go back and refer to the original construct of 'value' to orient their early stage design decisions (Monceaux and Kossmann 2012). Both aspects are of critical impact on investment risk certainty factor.

However, when moving from the macro level to the micro, this 'value' notion becomes blurrier, and contextual understanding gets lost when requirements are communicated down the supply network (Monceaux et al. 2014). There, the actual struggle of component oriented engineers takes place, depriving the IS of the user-driven added value by following the original, presumably unnegotiable, IS specifications. Although more resilient to additional costs and multiplying iterations, such conservative approach can hardly maximize the desired added value (Isaksson et al. 2013).

The established IS supply processes, although effective in coordinating a definite pool of tasks and resources towards the predefined objective, cannot handle the early stages of innovative IS development, which requires continuous sharing of knowledge and negotiations embracing a range of interdisciplinary skills, experiences and tools originating at different, often distanced, entities. Narrowing down targets to local perspectives causes design teams to fail creating solutions configured in the most valuable way. Empirical observations show that when system-level requirements are not available or not mature enough, engineers dealing with the development of long lead-time sub-systems tend to target local optima, rather than opening up the design space (Bertoni et al. 2018). These 'local optima' seldom embody the best possible result for the overall system. Most likely they hinder the possibility of identifying solutions that would work even better and that maximize value (Collopy and Hollingsworth 2011).

Some authors underline the importance and poor results of gathering specific requirements for IS engineering. On the one hand, well defined requirements for an IS are known to be prerequisite to avoid customer disappointment. On the other hand, all too often the process of defining IS requirements is neglected, delayed or distributed across engineering teams. Many claim that failure to involve stakeholders or clients at this stage leads directly to uncontrolled cost increase. Conversely, to improve clarity, awareness and understanding of what should be included in a system design, and hence to minimize development time and later rework, iteration and negotiation with customers and stakeholders must be established since the earliest design phases (Jiao and Chen 2006; Withanage et al. 2010). Nonetheless, all too often the relation with customers is not managed in an intentional manner nor carried out consistently, resulting in overlapping or missing requirements for specific IS features, modules, layers, documentation. Research in established software engineering methods shows that, requirements elicitation is far from being a linear, monolithic process; rather, it follows a more concurrent process (Prasad 1999). Consequently, unlike the open innovation paradigm involving external real-life stakeholders, the established research focuses on empowering individual engineers like they are owners of the processes addressed by the systems they develop. It is claimed a significant part of the concurrent design method, that the individual engineer, not an external stakeholder, customer, nor future user, is given much more say in the overall design process due to the collaborative nature of concurrent engineering. Giving the engineer ownership is claimed to improve the productivity of the employee and quality of the product, based on the assumption that people who are given a sense of gratification and ownership over their work tend to work harder and design a more robust product, as opposed to an employee that is assigned a task with little say in the general process (Kusiak 1992).

3 Research Problem

The key problem analysed in this article is whether or not there are any unobvious values behind recent academic paradigms, such as the open innovation paradigm, and its implementations, such as digital innovation hubs, that could bring new value or increase the existing values for industrial R&D clients in the development of IT systems. From a business theory perspective, customer value refers to customers' perceptions of what they receive, in return for what they sacrifice (Zeithaml 1988). There are two aspects to customer value: desired value and perceived value. In order to assess value from industry 4.0 perspective one needs to dig deeper the notions of customer and value. This article focuses on the latter with minor references to the former.

Being an organization rather than individual, a manufacturing plant may employ thousands of professionals, all potentially having different perspectives on the value of delivered IT solutions. Additionally, partners of the manufacturing plant, such as service providers, hardware maintenance firms, external consultants and last but not least the logistics all assess the functionalities and features of the plant's IT layer from another angle. On this account, before starting a study, it takes to define and classify the notions of the key user, value, IT system.

In MIDIH project a collaborative approach to IT service development is proposed, by forming a network of digital innovation hubs, i.e. collaborative networks of research and business entities with complementary offerings. This approach calls for new value measurement tools and may discover novel values, absent in closed single provider settings. The collaborative MIDIH approach also redefines key notions, including values and their indicators from shared, intersubjective perspectives.

- Better use of internal transport,
- Better organization of work in the warehouse,
- Less consumption of internal transport by reducing storage space, Less electricity consumption in forklift trucks—by eliminating unnecessary movements on handling.

4 Problem Solution and Methodology

For sake of this article we propose an alignment of notions used within two analysed use cases—projects, MIDIH—Manufacturing Industry Digital Innovation Hubs and SymbIoTe—Symbiosis of Smart Objects across IoT Environment. While the latter project has been concluded and provides a full overview of IT value creation, the former MIDIH is in progress while writing this article, which enables us to continue observations and studies proposed in the final remarks of this article. Both projects focus on developing advanced IT tools that may enable new or more efficient processes within industrial environments. Moreover, both projects involve numerous R&D organizations, along with their perspectives and goals and a number of industrial partners, playing roles of pilot adopters of the developed IT tools. Therefore, by analysing these cases, we add a real-life layer to our otherwise theoretical considerations.

MIDIH project proposes a novel approach to the creation of technology based value proposition, influencing the investment risk in R&D. By experimenting with IS component development in DIH environments, MIDIH redefines the provider and the value and consequently proposes new tools for creating the value proposition. Unlike in Osterwalder's business model canvass, normally applied to a single product provided by a single vendor, MIDIH takes a DIH based collaborative provider approach, where the value proposition does not exist unless complementary resources are combined and integrated in a collaborative manner. Such multiple vendor value requires a more advanced consideration of ecosystem relations and value flows in order to properly analyse, plan and manage the value network across multiple stakeholders. For this purpose MIDIH redesigns the Osterwalder's canvass, combines it with the value network analysis tool and complements with the project's new DIH service portfolio analysis tool, covering as many as 34 service development factors embracing the actual collaborative service aspects in more detail than the classical single provider tools do.

In industrial IT research the customer is the business entity who orders IT R&D or development jobs and expects these jobs to be performed as planned, which in case of research is not always the case. From industrial client perspective, the overall value of IT R&D boils down to ensuring a positive balance between costs and benefits which is determined by the notion of IT R&D investment risk. Insights from transaction costs theory suggest that there exist three major sources of risk factors for IT outsourcing: the transaction, the client and the supplier (Bahli and Rivard 2005) divide the three risk sources into seven risk factors—Table 1. These are the factors that industrial ecosystems are familiar with and hence these factors are intentionally managed by businesses.

However, apart from those well-known key factors, there may be other factors and related values, largely ignored by the industrial environments, yet having significant impact on the overall IS design risk. The hypothesis we are analysing here is that

Table 1 Risk factors in IT outsourcing operation. (*Source* own study)

Source of risk	Risk factors
Transaction	Asset specificity
	Small number of suppliers
	Uncertainty
	Relatedness
	Measurement problems
Client	Expertise with the IT operation
	Expertise with outsourcing
Supplier	Expertise with the IT operation
	Expertise with outsourcing

by intentionally managing these new, unobvious risk factors, industry could lower their investment risks and consequently boost their innovation and research activity (Table 2).

MIDIH project has made a new source of risk, ecosystem, evident and covering an array of risk factors. However in this article we focus only on a single, high impact factor—uncertainty—potentially including values going beyond the obvious business criteria. In the context of IT outsourcing, uncertainty may be present because [...] the transacting parties have incomplete or imperfect information, or because there are numerous unimaginable possibilities, which may arise during the course of the transaction. This means that, in the face of uncertainty, contracts are unavoidably incomplete, and may require renegotiation and frequent adjustments when unexpected contingencies occur. This renegotiation adds to ex ante costs and postpones the realization of outsourcing's perspective value. Ultimately, the resolution of ex ante uncertainty must wait ex post reality (Pilling et al. 1994).

Table 2 Risk factors largely ignored by the industrial environments. (*Source* own study)

Source of risk	Risk factors	Related added values from DIH approach	Level of impact on risk
Transaction	Asset specificity	Improved understanding	Low
	Small number of suppliers	Collaborative supply options	Mid
	Uncertainty	Early and thorough validation of assumed desired features	High
	Relatedness	Multiple interdependence	Low
	Measurement problems	Broad access to academic measurement tools	Low
Client	Expertise with the IT operation	Extended area-specific pool of IT expertise	Mid
	Expertise with outsourcing	Improved access to shared services and consultancy firms	Low
Supplier	Expertise with the IT operation	Extended area-specific pool of IT expertise	Mid
	Expertise with outsourcing	Improved access to shared services and consultancy firms	Low
Ecosystem	IPR management	Alternative IPR options	High
	Technology lifecycle management	Transparent distribution of responsibilities and costs	High

Fig. 1 View of of living laboratory—SymbIoTe project

The data for this part of analysis have been gathered in a living laboratory mode concentrating at three workshops, carried out every six months within SymbIoTe project—Fig. 1.

During workshops the same value-related questions were asked to check the correctness and level of certainty about values expected by industrial partners. Initially, R&D partners, in this case suppliers of IS, listed the values they had assumed key for their clients—industrial partners. Later, those same categories of values were collected from industrial partners. Finally, after the initial failed validation process, values listed by both sources were once more gathered, combined and completed. The study reveals that prior to the involvement of industrial partners the levels of certainty about assumed values were high, even though very generic and in some cases incorrect. Only after listing values by industrial partners the values assumed by R&D could have been validated.

The revealed discrepancy between values assumed by suppliers and expected by clients had an impact on the definition and execution of the developed technology components and further IS functionalities. For instance, interoperability of sensor data across modules and levels was one of the core system assumptions. However, it was only after DIH workshops that camera entered the subject matter pool of sensors as video recordings were indicated by consumers the type of data needed in such systems, which had never been considered before. Without repeatedly guiding both suppliers and clients through the IS usage scenarios, the resulting IS prototype would have been construed accordingly with the suppliers' initial assumptions. Consequently, the resulting proof of concept IS tools would not have met the expectations of clients to the level it finally did.

In MIDIH project the mutual sharing of resources (data and infrastructures) and complementing competences is observed to bring the critical added value for industrial partners. The usage of FIWARE architecture and its Arrowhead components, built by a numerous R&D, in combination with middleware and hardware elements coming from MIDIH partners gave birth to a robotic arm demonstrator, operating in a flat structure in factories giving superior managerial and analytical qualities surpassing those of the pyramid PLC based structure. Another interesting result is the logistical monitoring systems, developed by FIAT Research Centre in collaboration with Cefriel and Engineering. Here, CPS/IoT Technologies have been adopted, and, leveraging on MIDIH Open Platform and on the methodologies that have been developed within the project, it has been possible to enable the optimization both of Inbound Logistics Processes (Smart Supply Chain scenario) and Industrial Processes (Smart Factory scenario) in FCA. Consequently, a scenario has been developed where international logistics can monitor a container condition live and from historical data, indicating cases of free fall, side falling and crossing parameters such as humidity or temperature. Likewise in SymbIoTe, this and other MIDIH project industrial solutions would have missed critical requirements had it not been for the collaborative open approach at early development stages, involving multiple stakeholders on both provider and customer sides.

5 Conclusions and Further Works

Values sought for by academics pushing state-of-the-art resulting from the open innovation paradigm, i.e. opening up for external ideas and allowing internal ideas outside or early involvement of industrial partners in IT R&D, may add substantially to the values desired by industrial clients, in it to lowering R&D investment risk, by raising transactional certainty and enabling new unobvious industrially desired benefits. At present, the industrial benefits grow unintentionally in science-to-business consortia and their economic potential lingers largely undisclosed. It takes further research to verify if intentional open innovation could bring substantial increase of the desired value for industry and consequently raise the uptake of R&D projects results.

An array of interdisciplinary research would be needed, involving disciplines such as IT engineering, design and economy, to identify and propose respective IS design risk management tools. The issue analysed in this article merely touches the surface of a broader problem of added value generation and maximization across the whole innovation development up to TRL9 and lifecycle. An extended research is needed to assess more collaborative approaches and tools and to analyse their specific implementations.

Acknowledgements The work was carried out as part of the Project no. 767498 “Manufacturing Industry Digital Innvation Hubs”, financed by European Union Framework Programme for Research and Innovation Horizon 2020.

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