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MANAGING THE COMPLEXITY OF LARGE-SCALE RFID ROLLOUT PROJECTS IN LOGISTICS

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Abstract

The adoption and diffusion of RFID in logistics falls short behind the optimistic expectations shaped years ago. The complexity of large-scale RFID rollout projects is a barrier for widespread adoption and diffusion of RFID. Current RFID specific project management frameworks address the implementation of isolated RFID projects but provide very limited guidance on how to manage large-scale RFID rollouts. This paper provides substantiated insights on fuzzy front-end activities in the early phase of RFID rollout projects at a large automotive manufacturer. Our findings indicate that indivisibility as the underlying source of complexity is one of the principal factors for hesitant adoption and diffusion of RFID in automotive logistics. We propose fuzzy front-end approaches to address identified complexity issues and ramp up RFID implementation in a diverse cross-company and multi-project environment.

Keywords: RFID, Project Management, Complexity, Divisibility.

1 Introduction

Radio Frequency Identification (RFID) is expected to increase supply chain efficiency and transparency (McFarlane and Sheffi 2003; Gaukler and Seifert 2007; Wamba and Bendavid 2008). After years of hyping RFID it becomes evident that the actual adoption and diffusion rates in logistics networks of the manufacturing industry and particularly in the automotive industry (Schmitt et al. 2007) fall short of the expectations. RFID has been used for years to support production control and asset management (Fleisch et al. 2004) but implementations in cross-company logistics are still scarce (Schmitt et al. 2008; Krasnova et al. 2008; Bourgault and Bendavid 2010).

IT system development (ISD) is often referred to as being complex (Kirsch 1996; Wateridge 1997; Jurison 1999; Murray 2000; Xia and Lee 2004, 2005; Benbya and McKelvey 2006). RFID projects have been labelled complex accordingly (Bendavid and Bourgault 2005; Fish et al. 2006; Spekman and Sweeney 2006; Chang et al. 2008; Schmitt et al. 2007, 2008; Bottani et al. 2009; Kapoor et al. 2009; Bendavid and Bourgault 2010; Bourgault and Bendavid 2010). Project managers need to consider a series of physical properties and restraints. This particularly applies for the automotive industry: Firstly, RFID signals are subject to metal shielding effects and signal reflections (Strassner and Fleisch 2003) that raise demand for high performance tags and elaborated false-positive features. Secondly, the automotive industry makes extensive use of returnable transport items (RTIs). Isolating specific container flows for experimenting with RFID technology is difficult to achieve (Schmitt et al. 2008). Thirdly, the automotive industry is already a highly automated industry sector (Bovenschulte et al. 2007), therefore technological migration is of particular concern (Wu et al 2006; Chao et al. 2007). Technical complexity – 'the degree to which an innovation is perceived as relatively difficult to understand and to use' (Rogers 1983, p.230) – has been identified as one of the principal factors for hesitant RFID adoption and diffusion in the automotive industry at the time (Schmitt et al. 2007). However, three years have passed since then. It seems reasonable to assume that the automotive industry has had sufficient time to solve technical issues. Beyond that technical complexity by itself provides poor argumentation for the lack of adoption and diffusion. Practitioners and researchers require a profound understanding of complexity in order to align their research and implementation strategies respectively. Relevant literature falls short in exploring complexity and its impact on large-scale RFID rollouts. Existing concepts and methodologies are primarily concerned with the execution of single RFID projects (Bendavid and Bourgault 2005). They provide little guidance for extensive rollout scenarios and particularly ignore the need for pre-project or 'fuzzy-front' activities before actual project implementation (Reinertsen 1999; Koen et al. 2002). In this paper we aim to close the identified research gap. We address the following research questions:

What are the characteristics of complexity in large-scale RFID rollout projects? What are the implications for RFID project management? How can the industry reduce or avoid complexity in the fuzzy front-end of large rollout projects in order to drive gradual RFID migration?

This paper is organized as follows. In Section 2 we conduct a literature review and provide a differentiated view on complexity project management and innovation research. Section 3 describes applied methodology. In Section 4 we present the main findings of an in-depth case study conducted at the Volkswagen Aktiengesellschaft. Finally, in Section 5 we summarize our results and propose fuzzy front-end activities to address complexity in large-scale RFID rollout projects.

2 Literature Review

Complexity has been defined as difficulty in predicting the behaviour of a system given a known set of underlying components and properties (Weaver 1948), 'made of a large number of parts that interact in a nonsimple way' (Simon 1962, p.468) and 'consisting of many varied interrelated parts' (Baccarini 1996, p.202). At the core the proposed definitions agree that complexity sources in the existence of multiple objects and related interdependencies. However, literature does not propose a uniform definition of complexity. Exact meaning and interpretation varies depending on the practical and scientific background of the observer and often is difficult to be conceptually separated from perceived difficulty or uncertainty (Baccarini 1996). Literature emphasizes the subjective character of complexity (Downs and Mohr 1976; Tornatzky and Klein 1982; Gopalakrishnan and Damanpour 1994; Rogers 2003). Even though some of its characteristics may be quantified (Edmonds 1999; Xia and Lee 2005), complexity itself remains subject to perceptual influences.

Project management and innovation research put forward the concepts of technical, organizational and structural complexity (Rogers 2003; Tornatzky and Klein 1982; Pelz 1985; Kwon and Zmud 1987; Leonard-Barton 1988; Gopalakrishnan and Damanpour 1994; Damanpour and Gopalakrishnan 1998, Baccarini 1996, Williams 1999). The proposed concepts in project management and innovation research are generally associated with negative project performance (Liu 1999; Jurison 1999; Murray 2000; Tatikonda and Rosenthal 2000; Thorogood and Yetton 2004; Xia and Lee 2004, 2005; Benbya and McKelvey 2006) and negative influence on adoption/ diffusion behaviour (Rogers and Shoemaker 1971; Tornatzky and Klein 1982; Leonard-Barton 1988; Gopalakrishnan and Damanpour 1994) respectively. Terminology varies and partially overlaps. We summarize the proposed concepts as follows:

- Technical complexity of an IT project refers to technological characteristics that influence user handling as well as technological fit in terms of putting the technology into practice; e.g. dealing with false positive reads in industrial environments.
- Organizational complexity of an IT project originates from the alignment of business units and related interdependencies as well as underlying administrative frameworks and guidelines; e.g. resource conflicts, standards and regulations.
- Structural complexity of an IT project relates to the underlying structure of the implementation or rollout. It describes the parts and challenges a problem consists of, related tasks and interdependencies. Hence structural complexity highly depends on project setting and environmental conditions and restraints; e.g. due to capacity utilisation in goods receipt a minimum of RTIs needs to be tagged.

Simon (1962) addresses the concept of divisibility as a means of reducing complexity. He argues that the divisibility of complex systems into self-contained subsystems facilitates problem solving. Human problem solving is based on selectionism and/or trial and error (Sommer and Loch 2004). The ability to isolate and solve specific problems results in prototype solutions which later on may be applied and adapted to solve related problems in other application areas. Hence the divisibility of a complex system contributes to the self-reproduction of its subsystems (Simon 1962). Project management research (Murray 2000; Xia and Lee 2004) and innovation research (Rogers and Shoemaker 1971, p.155; Tornatzky and Klein 1982; Pelz 1985; Leonard-Barton 1988; Fichman 1992, 1999, 2004; Gopalakrishnan and Damanpour 1994) recognize divisibility as an essential implementation characteristic that positively influences project performance and the adoption and diffusion behaviour. In terms of project management divisibility helps to reduce interdependencies, uncertainty and risk. Regarding adoption and diffusion, divisibility allows for gradual implementation stages in such a way that each individual implementation stage positively contributes to the business result even if no further steps are taken (Rogers 1983, p.366; Ettlie 1986, p.80; Leonard-Barton 1988; Fichman 1999, 2004).

Frenken (2006) points out the temporal dimension of complexity and divisibility. Subsystems are subject to evolutionary pressure (Simon 1962). The local adaptation of subsystems to cope with specific business needs lead to continually evolving niche solutions. Subsequently these subsystems need to be streamlined and integrated to improve overall system performance, thus divisibility may be seen as both countermeasure and source of emerging complexity (Holland and Miller 1991). Innovation and project management research agree that divisibility is an important factor for implementation success. Finding the appropriate degree of divisibility is challenging and depends on specific project characteristics (Leonard-Barton 1988; Murray 2000).

The literature review provides a simple and theoretical yet fundamental approach for companies facing individual projects and large-scale RFID rollouts: Proper project selection in the early fuzzy front-end phase of technology rollouts is of particular importance (Reinertsen 1999; Koen et al. 2002; Bendavid and Bourgault 2010; Bourgault and Bendavid 2010). Given that the selected project deals with a representative case on how the company conducts business, the elaborated prototype solution will be adopted and taken as a blueprint to spread RFID technology throughout the corporate process and IT-infrastructure (Simon 1962). Divisibility is a crucial factor for successful project management and the adoption and diffusion of RFID; however, in the long term, applying divisibility principles will also lead to local adoption and adaptation behaviour thus shift complexity issues from the early rollout phase to later ones that will be shaped by foreseeable demand for ex post integration.

3 Methodology

This paper summarizes the results of a 12 month case study conducted in the context of project LeoPARD (Logistic Process Acceleration Trough RFID) at Volkswagen Aktiengesellschaft. Project LeoPARD is one of the first cross-company projects in automotive logistics. So far there are very few inter-organizational supply chain implementations (Bourgault and Bendavid 2010). We expect that our research produces useful insights and contributes to the ongoing discussion on RFID specific project management frameworks and the adoption and diffusion of RFID technology.

Our methodology is based on a literature review and semi-structured expert interviews. We identified three principal dimensions of complexity: technical, organizational and structural complexity (Section 2). These dimensions were used to structure our interviews and evaluate data. We interviewed a total of 12 project members from both Volkswagen Aktiengesellschaft and two participating suppliers (S1, S2). The interview partners were of operational, planning and managerial background. According to Anderson (1999) agents in complex systems act only on information that is available in their immediate working environments. We therefore strictly separated data that was collected at Volkswagen Aktiengesellschaft and data collected at the supplier facilities.

Practitioners do not necessarily distinguish between difficulty, uncertainty and the concepts of technical, organizational and structural complexity (Baccarini 1996). We applied a two-step Delphi approach to ensure and confirm interview results. In the first interview round we targeted complexity but documented any data that was referred to as challenging in terms of difficulty, uncertainty and complexity. Subsequently we evaluated the obtained data and classified according to I) difficulty, II) uncertainty, IIIa) technical complexity, IIIb) organizational complexity and IIIc) structural complexity. Perceived difficulty and complexity are particularly difficult to distinguish. Hence we looked for interdependencies in order to distinguish between plain difficulty and complexity. In the second interview round we discussed our results with the core team of the project. We asked the core team to assess and revise our classification. Finally, the interviewees were asked to propose solutions to the identified complexity issues and rank the issues according to the priorities A) highly relevant and B) relevant for future rollout success.

4 Case Study

Project LeoPARD was conducted at the Wolfsburg plant and nearby supplier facilities in 2008/2009. The focus of the project was on material logistics. Two of approximately hundred relevant RTI types were chosen to be tagged. A total of 3000 Volkswagen owned containers was equipped with high value passive UHF tags (868 MHz). Both of the chosen container types had to be tagged with two RFID tags in order to cope with metal shielding effects. Traditional barcode labels provided for backup and downstream process integration. LeoPARD is a representative case for RFID implementation in push-based logistic process design. After corresponding material call-offs had been received via Electronic Date Interchange (EDI) the supplier proceeded the outbound of associated package items. The suppliers attached Global Transports Labels (GTLs) to the package items and used hybrid mobile handhelds to copy package item information to the RFID tag. At Volkswagen Aktiengesellschaft RFID equipped forklifts were used to identify incoming materials and increase process efficiency in goods receipt. The bulk reading capabilities of RFID technology enabled the operators to identify four package items at a time. The pilot project was announced to be a breakthrough for RFID in material logistics (Volkswagen AG 2009). Currently Volkswagen Aktiengesellschaft is engaged in follow up rollout activities. 1.5 years after the project has been finished project members are still struggling to overcome implementation hurdles and expand the scope of the project from pilot stage to large-scale rollout. We explored the case of LeoPARD in terms of complexity and divisibility (Table 1, 2).

ID	Source(s)	Challenge	Concept(s)*	Divisibility	Relevance	Proposed Solution
1	Logistics Manager S1, S2	Running RFID and traditional barcode processes for diverse customers increases process complexity.	U, OC	Low	A	Drive data and process standardisation among customers to enable standard outbound procedure.
2	IT Manager S1; Logistics Manager S2	Tagging package items shortly before they are sent to the customer (‘Slap and Ship’) requires additional process steps that negatively effect process efficiency.	U, TC	Low	A	Fully integrate technology into supplier’s IT and process landscape. Problematic: IT strategy does not depend on individual supplier plants but on a corporate decision.
3	IT Manager S1	Package item information is written to the RFID tags and communicated in the customer’s EDI call-off shortly before the parts are shipped. The package items are stored and transported in bulks. In the case of RFID the previously stored package items need to be separated before the information is written to the RFID tag in order to make sure that the information is written to the target tag(s) only. This procedure reduces process efficiency and adds process complexity.	D, OC	High	B	Establish RFID tunnels that allow writing RFID information to the RFID tags more efficiently. Alternatively rollouts could focus on pull-based logistic processes. In pull-based processes such as Just in Time and Just in Sequence the parts are produced after the customer’s EDI call-off is received. The transport information can be written to the package item as part of the manufacturing process. At this stage the package items are separated already.
4	Operators S1, S2	Due the RTI characteristics two tags had to be attached to each container. Information had to be written to both tags making it difficult to find an appropriate writing angle.	D	High	B	Standardize tag position and select appropriate RFID tag to deal with shielding effects. Influence container design so that only one tag needs to be attached to each RTI.
5	Operators S1, S2	Difficulties operating the new technology.	D	High	B	Additional Training. Establish First Level Support.

***** Difficulty (D), Uncertainty (U), Technical Complexity (TC); Organizational Complexity (OC); Structural Complexity (SC)

Table 1. Complexity/ Divisibility from the Supplier Perspective

At the time the involved suppliers are primarily concerned with process standardization [1], IT integration [2] and process efficiency [2, 3]. From the supplier’s point of view the most challenging factors for future RFID rollouts are dealing with ambiguous customer requirements and adjusting IT-infrastructure and process integration. Both aspects show low divisibility. Suppliers have little influence on the customer’s adoption behaviour thus depend on external adoption decisions. Multiple customers need to adopt RFID and matching communication standards in order to resolve complexity on the supplier side. The supplier needs to fully integrate RFID into the IT- and process landscape to overcome ‘slap and ship’ inefficiencies. Process design and corresponding IT strategy usually does not depend on individual supplier plants but on corporate decisions. Uncertainty regarding the future prevalence of RFID is of particular importance. Headquarters will not decide to shift towards RFID unless binding long term agreements have been made with the customer side. The suppliers are also concerned with technical issues such as operating the new technology [4, 5]; however, there is a high probability that related problems can be resolved on the project-level, hence they do not necessarily contribute to rollout complexity.

ID	**Source(s)**	**Challenge**	**Concept(s)***	**Divisibility**	**Relevance**	**Proposed Solution**
6	Logistics Coordinator, Logistics Planner	Goods receipt areas need a minimum of RFID based business transactions in order to be cost-effective; to meet the required quanities not just special-purpose RTIs but universal RTIs need to be tagged, many of which only occasionally pass the RFID enabled goods receipt area.	SC	Low	A	Avoid open-loop and semi-closed container cycles. Focus on 1:1 manufacturer-supplier relationships that use special-purpose rather than universal containers.
7	Logistics Coordinator, Logistics Planner	Dealing with both barcode and RFID processes increases complexity and negatively effects process efficiency.	U, OC	Low	A	Select divisible process scenarios that allow to rapidly shifts towards direct RFID implementation.
8	Logistics Coordinator, Logistics Planner	Due to metal shielding and reflections two RFID tags had to be mounted to each container. This complicates writing on the supplier side. Moreover it severely affects the overall business case.	TC	High	A	Work with technology and RTI providers on container design and optimal tag position before new containers are introduced to the container cycle.
9	Logistics Coordinator, Logistics Planner	Many different RTIs with variable contents and characteristics make it difficult to select appropriate tags and tag position.	U, D	High	B	Run extensive RTI and hardware tests before starting with the rollout.
10	Logistics Coordinator, Logistics Planner	Due to large RTI volumes and process intransparency it is difficult to find/ tag all RTIs.	U, D	High	B	Tag all new RTIs that enter the cycle. Prepare for extensive tagging scenarios.
11	IT Manager, IT Project Leader	Uncertainty regarding the future role of RFID and required changes in IT infrastructure.	U, D	High	B	Actively drive discussion with responsables from technical areas.

12	IT Project Leader	LeoPARD requires GTL label for backup and integration reasons. Currently many suppliers work with outdated barcode labels.	D, OC	Low	A	Drive rollout of GTL label before addressing further RFID rollouts.
13	IT Project Leader	Inconsistent EDI quality. In order to check RFID scannings against EDI data quality needs to approach 100%.	D, OC	High	B	Establish a program that ensures continuous improvements of supplier's EDI data quality.
14	Logistics Coordinator, Logistics Planner	Fork lifts in goods receipt are used interchangeably with other production and warehouse areas. Even though just few fork lifts are used in the project all fork lifts in the related areas will need to be equipped with RFID readers and antennas.	OC, SC	Low	B	Restrict the interchange of forklifts or negotiate leasing rates for RFID equipment that allow equipping all fork lifts at low cost. Alter-natively search for solutions that allow to implement RFID gates in goods receipt.
15	RTI Management	Strategic alignment of Purchasing Department and RTI Department. The departments need standard organizational guidelines to participate in RFID rollouts.	D, OC	High	B	Develop guidelines and standard procedures for all stakeholders involved in large-scale rollouts.
16	Logistics Coordinator, Logistics Planner	Negative business case if RFID concepts are applied in goods receipt only.	D	Low	A	Negotiate tag prices/ wait until tag prices drop. Drive process integration to increase return of invest (ROI) per tag.
17	Team	Unpredictable adoption and diffusion rates at the supplier facilities and Volkswagen AG.	U	High	A	Focus on divisible project scenarios to minimize risk.

***** Difficulty (D), Uncertainty (U), Technical Complexity (TC); Organizational Complexity (OC); Structural Complexity (SC)

Table 2. The Complexity/ Divisibility from the Volkswagen Perspective

The project teams aims to gradually expand the scope of developed RFID concepts. Our interviews show that the expansion of project scope comes with several implications. The project team identified a series of challenges which need to be addressed in order to continue with the rollout activities. Uncertainty regarding the future adoption and diffusion at Volkswagen Aktiengesellschaft and at the suppliers [11, 17] cannot be resolved but related risks can be reduced by applying divisibility principles. Some of the identified issues are difficult to handle, but can be dealt with in an isolated manner [9, 10, 16]. Others show some degree of complexity but adequate solutions have been proposed [7, 8, 14, 15]. Solutions possibly require changes in today's process design; e.g. restricting the interchange of forklifts [14] but related impacts may be seen as an acceptable trade off which helps to resolve complexity and improve the overall business case.

The rollout of project LeoPARD is dealing with one key aspect which may be understood as the source of complexity in push-based process environments and as a hurdle for further rollout activities. Open-loop RTI cycles as implemented in push-based process design require the tagging of large RTI quantities most of which do hardly generate any benefits in the early rollout phase [6]. They mostly circulate in environments which have not been equipped with RFID technology yet, thus do not contribute to the business case of the specific rollout stage. It is particularly difficult to identify isolable RTI cycles that allow for applying divisibility principles. In fact the very next rollout phase of LeoPARD requires jumping from two suppliers and 3.000 tagged containers to 25 suppliers handling a total of 91.500 RTIs. In consequence Volkswagen Aktiengesellschaft and the involved suppliers need to establish an entire hardware and IT-infrastructure in order to justify related investment decisions. The suppliers need to fulfil prerequisites such as the ability to manage Global Transport Labels (GTL) [12] and to deliver adequate EDI data quality [13]. Supplier integration exponentially increases organizational complexity and expands the preparation phase of large-scale RFID rollouts. Project LeoPARD is a representative case for RFID implementation in push-based automotive process design. Once a prototype solution has been established there is a high probability that the approach will be adopted and diffused throughout the corporate process landscape, however, due to the lack of divisibility in open-loop RTI cycles the LeoPARD team postponed the rollout and is now searching for alternative process scenarios to initiate technology migration. Project LeoPARD shows that the structural complexity, interdependencies and restraints in logistic practice set physical limitations to modular project management practise and incremental RFID implementation. From the project management perspective the lack of indivisibility contradicts with frequently-quoted KISS (Keep It Small and Simple) principles or SMART (Specific Measurable Assignable, Realistic, Timely) criteria for successful project management (Murray 2000). From the innovation perspective indivisibility prevents Volkswagen Aktiengesellschaft from implementing gradual rollout stages in which each individual stage positively contributes to the business result (Leonard-Barton 1988; Fichman 1999, 2004). LeoPARD emphasises the importance of initial project selection and long term project preparation in the fuzzy front-end of large-scale RFID rollouts. The pilot project suggests multiple lessons learned for further rollout activities. Based on the results of Rochel and Royce (2006) we split the recommend front-end measures into two different types: I) Activities that result beneficial but could have been realised before the advent of RFID technology, i.e. RFID technology is used as a medium to integrate IT-systems and incrementally improve overall supply chain performance at very low risk and II) technology specific activities that involve potential change in management practise:

Front-end activities type I:

- Drive data and process standardization to overcome organizational complexity
- Streamline barcode practice. Make sure that one unique barcode label is used consistently along the supply chain. The document serves as a backup for RFID technology thus forms part of a strategic migration framework to shift from barcode to RFID technology (e.g. rollout of the GTL label).
- Drive programs that ensure high quality EDI exchange that provides for reliable communication between the supply chain stakeholders and can be used to verify RFID readings on the customer side.

Front-end activities type II:

- Select project scenarios which are both divisible and representative for the corporate way of conducting business
- Run extensive hardware and RTI tests before initiating large-scale RFID-rollouts
- Identify RFID potentials on the supplier side and help suppliers to fully integrate RFID rather than running ‘slap & ship’ approaches
- Work with tag providers and RTI manufacturers to develop appropriate RFID tags and influence RTI design respectively
- Negotiate master agreements for buying large volumes of RFID tags and reading infrastructure
- Negotiate leasing contracts with RFID technology providers to reduce initial technology investment
- Establish support and service infrastructure
- Develop corporate guidelines and standards to reinforce the commitment of all stakeholders involved (e.g. purchasing and container management department)

Although some of the lessons learned are case-specific the majority of measures is generic and provides guidance to other companies facing the fuzzy front-end phase of large-scale RFID rollouts. One of the most essential lessons learned from project LeoPARD is that structural complexity in push-based process design cannot be resolved; however, it may be avoided. We found indications that RFID implementation in pull-based process design such as Just in Time (JIT) and Just in Sequence (JIS) procedures represent a viable alternative. JIT/ JIS is standard practise in automotive logistics (Collins and Bechler 1997; Strassner 2005; Schmitt et al. 2008) and is representative for how automotive manufacturers conduct business. There are indications that RFID implementation in pull-based processes is less demanding in terms of complexity. In push-based processes the supplier receives material call-offs after the components have been produced. Subsequently the supplier needs to separate the package items stored in the warehouse to write package item information to the RFID tags before the shippings are sent to Volkswagen Aktiengesellschaft. In pull-based processes such as JIT and JIS the call-off information is received before the components are produced. After the components are produced they are not stored but directly shipped to the customer. Essential shipping information is known prior to production start and can be written to the RFID tags as part of the normal manufacturing process. In push-based process design, goods receipt at the customer is an essential process step to document physical material transfer and to trigger corresponding financial transactions. Goods receipt areas need a minimum of RFID based business transactions in order to be cost-effective thus limit the divisibility of applicable rollout strategies. JIT/ JIS processes do not implement traditional goods receipt. Incoming shipments are directly transferred to buffer areas or to the production line. After the cars have been manufactured invoicing is triggered according to the number of components that actually has been assembled. The identified differences in process design come with essential implications. In JIT/ JIS environments RFID implementations do not have to deal with the limitation of capacity utilisation in goods receipt. Additionally RFID implementation may provide enhanced transparency features without coping with the accuracy that is required to support goods receipt and related business transactions. Unlike in the case of push-based process design incoming shipments need to be identified rather than authenticated which moderates the standards for data reliability. JIS processes are particular interesting for RFID implementation as they are likely to provide a reasonable degree of divisibility. JIS design generally implements special purpose RTIs for car-specific modules. These RTIs usually circulate in 1:1 supplier-customer relationships. Incremental rollout stages that apply divisibility principles need to address a limited number of stakeholders and a manageable quantity of RTIs only.

5 Conclusions

Our research categorises RFID project management challenges by the concepts of difficulty, uncertainty, technical complexity, organizational complexity and structural complexity. Our results suggest that implementation challenges that correspond to difficulty, uncertainty and technical complexity can be solved by using divisibility principles. They contribute to overall complexity but standalone they may not be seen as the determining factor for project failure and delayed RFID rollouts in the automotive industry. The principal challenge in cross-company logistics is dealing with organizational issues which stem from underlying structural complexity – that is the indivisibility of semi- and open-loop RTI cycles in push-based process design. In consequence rollout activities need to address more than just 1:1 supplier-customer relationships but comparatively large subsets of the supply chain network. Based on our research results we confirm the proposition of divisibility as an essential factor for project success and as prerequisite for incremental RFID implementation and rollout design. There is reasonable evidence to assume that one of the key factors for successful rollout strategies is the identification of project scenarios that show an adequate degree of divisibility and at the same time are representative for the way the company conducts logistic business. Adopting Simon’s (1962) core principles identifying such project scenarios will have two positive effects. Divisibility facilitates the execution of individual projects. Beyond that developed prototype solutions are more likely to be adopted and propagated at the corporate level thus positively affect the adoption and diffusion of RFID. Structural indivisibility in that sense is one of the reasons for delayed RFID adoption and diffusion in automotive logistics.

Case selection partially limits our findings to push-based process design. However, the majority of lessons learned that were put forward is generic by nature. LeoPARD is one of the first automotive pilot projects that aims for RFID implementation in cross-company material logistics and provides insights on how to shape the fuzzy front-end of large-scale rollouts thus contributes to the ongoing discussion on RFID adoption and diffusion and related project management practise. Although the search for a reasonable degree of divisibility regarding RFID implementation remains subject to further research, we found evidence that pull-based process design provides a favourable alternative to push-based process design. As JIT and JIS is standard practise in automotive logistics we suggest that researchers and practitioners direct their attention to the potentials and challenges of RFID implementation in JIT/ JIS environments.

Researchers and practitioners should also consider the long-term strategic trends in automotive manufacturing. The industry is shifting towards modular consortia strategies (Collins and Bechler 1997; Doran and Hill 2009; Gneiting 2009). Modular concepts enable component sharing among multiple vehicle platforms. Modularization is expected to affect the underlying strategic framework for large-scale RFID rollouts. As modular strategies go along with JIT/ JIS practice they may have positive effects on divisibility. However, increasing modularization will also lead to RTI assimilation and standardisation thus cause increasing indivisibility on the container management level. Further research shall address long-term trends in automotive manufacturing and explore the implications for large-scale RFID rollouts.

References

Anderson, P. (1999) Complexity Theory and Organization Science. Organization Science, 10 (3), 216-232.

Baccarini, D. (1996) The concept of project complexity – a review. Int. J. of Project Management, 14 (4) 201-204.

Benbya, H. and McKelvey, B. (2006) Toward a complexity theory of information systems development. Information Technology & People 19 (1) 12-34.

Bendavid, Y. and Bourgault, M (2005) Positioning Project Management for RFID Implementation in a Multi-firm, Multi-Project Context. In Proc. of IAMOT, Vienna.

Bendavid, Y. and Bourgault, M. (2010) A living laboratory for managing the front-end phase of innovation adoption: the case of RFID implementation. Int. J. Organisation and Management, 2 (1), 84-108.

Bottani, E., Hardgrave, B., Volpi, A. (2009) A Methodological Approach to the development of RFID Supply Chain Projects. Int. J. of RF Technologies: Research and Applications, 1 (2) 131-150.

Bourgault, M. and Bendavid, Y. (2010) Introducing Complex Technologies into the Enterprise: The Case of RFID. In Sherif, M. H. (Ed.) Handbook of Enterprise Integration, CRC Press, Boca Raton, USA.

Bovenschulte, M., Gabriel, P., Gaßner, K., Seidel, U. (2007) RFID: Prospectives in Germany, Federal Ministry of Economics and Technology.

Chang, S.-I., Hung, S.-Y., Yen, D. C., Chen, Y.-J. (2008) The Determinants of RFID Adoption in the Logistics Industry – A Supply Chain Management Perspective. Communications of AIS, 23 (12) 197-218.

Chao, C.-C., Yang, J.-M., Jen, W.-Y. (2007) Determining technology trends and forecasts of RFID by a historical review and bibliometric analysis from 1991 to 2005. Technovation 27 (5), 268-279.

Collins, R., Bechler, K., Pires, S. (1997) Outsourcing in the Automotive Industry: From JIT to Modular Consortia. European Management Journal, 15 (5), 498-508.

Damanpour, F. (1996) Organizational Complexity and Innovation: Developing and Testing Multiple Contingency Models. Management Science, 42 (5), 693-716.

Damanpour, F. and Gopalakrishnan, S. (1998) Theories of organizational structure and innovation adoption: the role of environmental change. J. of Engineering and Technology Management, 15 (1), 1-24.

Doran, D. and Hill, A. (2009) A review of modular strategies and architecture within manufacturing operations. J. of Automobile Engineering, 223 (1), 65-75.

Downs Jr., G. W. and Mohr, L. B. (1976) Conceptual Issues in the Study of Innovation. Administrative Science Quarterly, 21 (4), 700-714.

Edmonds, B. (1999) What is Complexity? – The Philosophy of Complexity per se with Application to some Examples in Evolution. In Heylighen, F., Bollen, J. and Riegler, A. (Eds.) The Evolution of Complexity, Kluwer Academic, Dordrecht, 1-17.

Ettlie, J. (1986) Implementing manufacturing technologies: Lessons from experience. In Davis, D. and Associates (Eds.) Managing technological innovations, Jossey-Bass, San Francisco.

Fichman, R. G. (1992) Information Technology Diffusion: A Review of Empirical Research. In Proc. of the 13th Int. Conf. on Information Systems, Dallas.

Fichman, R. G. and Moses, S. A. (1999) An Incremental Process for Software Implementation. Sloan Management Review, 40 (2), 39-52,

Fichman, R. G. (2004) Real Options and IT Platform adoption: Implications for Theory and Practice. Information Systems Research, 15 (2), 132-154.

Fish, L. A. and Forrest, W. C. (2006) The 7 Success Factors of RFID. Supply Chain Management Review, 10 (6), 26-32.

Fleisch, E., Ringbeck, J., Stroh, S., Plenge, C., Strassner, M. (2004) From Operations to Strategy: The Potential of RFID for the Automotive Industry. M-Lab Reports, 23 19-21.

Frenken, K. (2006) Technological Innovation and Complexity Theory. Economics of Innovation and New Technology, 15 (2), 137-155.

Gaukler, G. and Seifert, R. W. (2007) Applications of RFID in Supply Chains. In Jung, H., Chen, F. and Jeong, B. (Eds.) Trends in Supply Chain Design and Management, Springer, London, 29-48.

Gneiting, P.R. (2009) Supply Chain Design für modulare Fahrzeugarchitekturen. Dissertation, ETH Zurich.

Gopalakrishnan, S. and Damanpour, F. (1994) Patterns of generation and adoption of innovation in organizations: Contingency models of innovation attributes. J. of Engineering and Technology Management, 11 (2), 95-11.

Holland, J. H. and Miller J. H (1991) Artificial Adaptive Agents in Economic Theory. American Economic Review, 81 (2), 365-370.

Jurison, J (1999) Software Project Management: The Manager's view. Communications of the AIS, 2 (3), 1-57.

Kapoor, G., Zhou, W., Piramuthu, S. (2009) Challenges associated with RFID tag implementations in supply chains. European J. of Information Systems, 18, 526-533.

Kirsch, L. J. (1996) Management of Complex Tasks in Organizations: Controlling the Systems Development Process. Organization Science, 7 (1), 1-21.

Koen, P. A.., Ajamian, G. M., Boye, S. Clamen, A., Fisher, E., Fountoulakis, S., Johnson, A., Puri, P., Seibert, R. (2002) Fuzzy front end: effective methods, tools and techniques. In Belliveau, P., Griffin, A., Sommermeyer, S. (Eds.) The PDMA ToolBook for New Product Development, Wiley, 5-35.

Krasnova, H., Weser, L., Ivantysynova, L. (2008) Drivers of RFID Adoption in the Automotive Industry. In Proc. of the 14th Americas Conf. on Information Systems, Toronto, 1-9.

Kwon, T. H and Zmud, R. W. (1987) Unifying the Fragmented Models of Information Systems Implementation. In Critical Issues in Information Systems Research, John Wiley & Sons, New York, 227-251.

Leonard-Barton, D. (1988) Implementation Characteristics of Organizational Innovations. Communication Research, 15, 603-631.

Liu, A. M. M (1999) A research model of project complexity and goal commitment effects on project outcome. Engineering, Construction and Architectural Management, 6 (2), 105-11.

McFarlane, D. C. and Sheffi, Y. (2003) The impact of automatic identification on supply chain operations. Int. J. of Logistics Management, 14 (1), 1-18.

Murray, J. P. (2000) Reducing IT Project Complexity. Information Strategy, 16 (3), 30-38.

Pelz, D. C. (1985) Innovation Complexity and the Sequence of Innovating Stages. Science Communication, 6 (3), 261-291.

Reinertsen, D. G. (1999) Taking the Fuzziness Out of the Fuzzy Front End. Research-Technology Management, 42 (6), 25-31.
Rochel, R. and Joyce, D. (2006) Impact of RFID Technology on Supply Chain Management Systems. In Proc. Of the 19th Annual Conf. of the National Advisory Committee on Computing Qualifications, Wellington.
Rogers, E. M. (1983) Diffusion of Innovations. The Free Press, New York.
Rogers, E. M. (2003) Diffusion of Innovations. The Free Press, New York.
Rogers, E. M. and Shoemaker, F. F. (1971) Communication of Innovations: A cross-cultural approach. The Free Press, New York.
Simon, H. (1962) The architecture of complexity. In Proc. of the American Philosophical Society, 106 (6), 467-482.
Sommer, S. C. and Loch, C. H. (2004) Selectionism and Learning in Projects with Complexity and Unforeseeable Uncertainty. Management Science, 50 (10), 1334-1347.
Spekman, R. E. and Sweeney II, P. J. (2006) RFID: from concept to implementation. Int. J. of Physical Distribution & Logistics Management, 36 (10), 736.754.
Schmitt, P., Thiesse, F., Fleisch, E. (2007) Adoption and Diffusion of RFID Technology in the Automotive Industry. In Proc. of the 15th European Conf. on Information Systems, St. Gallen.
Schmitt, P., Michahelles, F., Fleisch, E. (2008) Why RFID Adoption and Diffusion takes time: The Role of Standards in the Automotive Industry. Auto-ID Labs, 1-19.
Strassner, M. and Fleisch, E. (2003) The Promise of Auto-ID in the Automotive Industry. Auto-ID Center, M-Lab, 1-24.
Strassner (2005) RFID im Supply Chain Management – Auswirkungen und Handlungsempfehlungen am Beispiel der Automobilindustrie. Dissertation, University of St. Gallen.
Tatikonda, M. V. and Rosenthal, S. R. (2000) Technology Novelty, Project Complexity, and Product Development Execution Process: A Deeper Look at Task Uncertainty in Product Innovation. IEEE Transactions on Engineering Management, 47 (1), 74-87.
Thorogood, A. and Yetton, P. (2004) Reducing the Technical Complexity and Business Risk of Major Systems Projects. In Proc. of the 37th Hawaii Int. Conf. on System Sciences, Hawaii.
Tornatzky, L. G. and Klein, K. J. (1982) Innovation Characteristics and Innovation Adoption-Implementation: A Meta-Analysis of Findings. IEEE Transactions and Engineering Management, EM-29, 1.
Volkswagen AG (2009) Breakthrough for New Technology in Material Logistics. http://www.volkswagenag.com/vwag/vwcorp/info_center/en/news/2009/03/breakthrough_material_logistics.html, Last Access: 2010-09-23.
Wamba, F.S. and Bendavid, Y. (2008) Understanding the Impact of Emerging Technologies on Process Optimization: The Case of RFID. 13th Asian-Pacific Decision Sciences Conf., Queensland.
Wateridge, J. (1997) Training for IS/ IT project managers: a way forward. Int. J. of Project Management, 15 (5), 283-288,
Weaver, W. (1948) Science and Complexity, American Scientist, 36, 536.
Williams, T. M (1999) The need for new paradigms for complex projects. Int. J. of Project Management, 17 (5), 269-273.
Wu, N. C., Nystrom, M., Lin, T.-R. and Yu, H.-C. (2006) Challenges to global RFID Adoption. Technovation, 26 (12), 1317-1323.
Xia, W. and Lee, G. (2004) Grasping the Complexity of IS Development Projects. Communications of the ACM, 47 (5), 68-74.
Xia, W. and Lee, G. (2005) Complexity of Information Systems Development Projects: Conceptualization and Measurement Development. J. of Management Information Systems, 22 (1), 45-83.