PATH CREATION IN THE RAILROAD INDUSTRY: DIMENSIONS OF DESIGN IN IT-ENABLED INNOVATION

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Abstract

Taking a process research approach, we have followed a government agency in the railroad industry over a six-year-period as they have engaged in an IT-based innovation project. Providing empirical insights into this process and using path creation theory to analyse our case, we further our understanding of how IT-based innovations evolve over time by highlighting its multi-dimensional nature. We conclude that IT-based innovations cannot be fully understood from the material design dimension alone, i.e., by only focusing on the artefact. IT-based innovation affects and is affected also by what mental models we bring and what actors are engaged in the process. Our work thus contributes to the innovation research by showing that a focus on the material dimension only is insufficient and may result in a prolonged struggle that will not be resolved until looked upon also from a cognitive and/or organisational dimension. The inclusion of all these three dimensions from the outset may lessen the friction involved in IT-based innovation projects.

Keywords: path creation, dimensions of design, IT-based innovation, railroad industry

1 INTRODUCTION

During the last few decades there has been increasing demand on firms to innovate in order to stay competitive (McAdam, 2000; Hult et al., 2004). Lyytinen and Rose (2003) explain that while IT innovation in its simplest form may involve only the technological component, in reality it often has to be accompanied with and amplified by various organisational adjustments in order to be successful; e.g., new forms of processes, routines, business models, and/or organisational structures. However, it is often impossible to reinvent a whole business or an entire organisation all in once, and innovations must therefore, at least whilst being tried out, coexist with existing solutions. The problem is that these mature structures have dominating positions and thus influence negatively on innovation. To create purposefully a new trajectory by actively shaping an alternative future, requiring the organisation to rethink their current practice, therefore becomes challenging (Garud & Karnøe, 2001; Henfridsson et al., 2009). Adding further complexity, it has recently become apparent that these change processes often requires interactions between distributed actors, often belonging to different organisations (Boland et al., 2007). More research that examines how innovation affects organisations and how it plays out over time is thus needed.

In this paper we report from a longitudinal study of the Swedish railroad industry, which today consists of a palette of partly interdependent and partly competing actors, together trying to provide a functioning and sustainable transport solution. Competition is particularly evident in the operation section where there were 26 train operators in Sweden in 2009. To meet the demands of a market economy, these actors can seldom innovate in isolation; they need to form alliances and collaborative networks to produce the competitive offerings that allow them to attract customers and compete successfully with other modes of transportation. The railroad industry thus offers a good milieu to study what we refer to as IT-based innovation, i.e., innovation that exploits the generativity (Zittrain, 2006) of information technology to develop new services and/or relationships by transforming existing socio-technical structures.

To contribute to path creation as a theoretical lens for innovation studies, we have followed one organisation in detail as they have tried to renew and innovated the way in which they communicate with the surrounding world. We shall first account for path creation and its role in innovation studies before describing our research approach. Thereafter, describe four episodes of path creation activities which subsequently are discussed before we conclude with a summary of our findings.

2 A MULTI-PERSPECTIVE INNOVATION FRAMEWORK

Seo and Creed (2002) suggest that institutional changes are often prompted by the surfacing of contradictions. Painful as these conflicts may be for the organisations, they can prompt actors to rethink the way they operate and result in innovative leaps. The study of such conflicts thus provides researchers with excellent opportunities to understand better the emergence and establishment not only of different forms of organising but also of new mental. Garud and Karnøe calls such active departure from the routine "path creation", which should be understood as the purposeful deviation from a course prescribed by existing social rules and taken-for-granted technological implementations (2001, p.2). Path creation has proven to be a useful lens when trying to understand innovation models (cf., Garud & Karnøe, 2001; Boland et al., 2007; Henfridsson et al., 2009).

However, path creation in its original form focuses on entrepreneurs' path creation activities *in isolation* whereas more recent contributions to the innovation literature have emphasised the larger socio-technical context where new paths affect and interfere with one another, creating wakes of innovation (Boland et al., 2007). As a response, Henfridsson et al. (2009) have developed a model for understanding path creation that explicitly addresses the multi-faceted nature of innovation. In this paper we initially adopt and later modify Henfridsson et al.'s (2009) model. In doing so, we answer to

Henfridsson and colleagues' call to extend their work to industries other than the automobile industry and to more heterogeneous settings.

Having reviewed the innovation literature, Henfridsson and colleagues (2009) suggest a model that combines three layers of design; the material, the cognitive and the organisational. The material layer refers to the technological component, to the physical artefact itself, i.e., to an item which "can be seen, heard, touch, and used" (p. 4). The second layer is the cognitive layer, which should be understood as the mental frames that govern the way the designer structures the artefact and influence what functions to include. This is similar to the cognitive imageries that Ciborra and Lanzara (1994) suggest that the actor brings and routinely enacts in work as part of the formative context that the institution often comprises. Galunic and Rodan suggest that as (design) actions are externalised through artefacts, the designers' mental models become reinforced, and continue to guide subsequent interactions. As the mental models filter what information is actively processed, they create a "distorted perception" that increase the tendency to perceive data that primarily is congruent with one's own mental models and is detrimental to one's ability and willingness to change (Galunic & Rodan, 1998). The third layer is the organisational layer. The organisational layer specifies the various actors and their interrelationships but also the design process as such and aligns various activities with their corresponding organisational units (Henfridsson et al., 2009).

In each of these three design layers the organisation will be involved in various sorts of struggles between the existing and dominant structure on the one hand and the new and emergent structure on the other. These struggles are the contradictions, or dialectics in Henfridsson at al.'s vocabulary, upon which we shall focus our attention during the analysis. Henfridsson et al. explain that dialectics between dominant and emergent structures are not necessarily resolved once and for all. Instead, in enacting a new dominant structure, designers typically incorporate elements from the emergent structure and the residual structure, i.e., the remaining of an old dominant structure. This is illustrated in Figure 1.

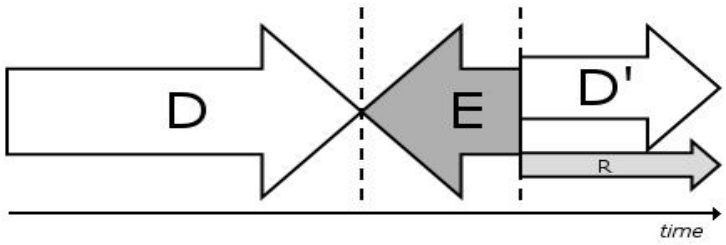

Figure 1. Dominant structure (D), Emergent structure (E), New Dominant structure (D') and Residual structure (R). Adopted from Henfridsson et al. (2009)

3 RESEARCH METHOD

To develop our understanding of how the process of IT-based innovations unfold over time, we followed Langley and Truax's (1994) example and conducted a longitudinal case study with three explicit data collection phases approximately 18 and 12 months apart, respectively. Langley and Truax (1994) explain that a longitudinal study enhances internal validity by facilitating the detection of possible cause-effect relationships. Because of these internal replication possibilities, useful insights can be deducted from a single case study (Langley, 1999).

In this work, we have studied the Swedish Railroad Administration (In Swedish; *Banverket* - BV). BV, established as a separate organisation in 1988, is a government agency responsible for maintaining the railroad infrastructure in Sweden, i.e., they monitor and conduct developments within the railroad sector, assist Parliament and the Government on railroad issues, are responsible for the operation and

administration of the national track system, co-ordinate the local, regional and interregional rail transport and provide support for research and development on railroad matters.

Since the beginning of this millennium, BV has supported a multitude of different data formats and interfaces when handing out information to other railroad actors. All these customers (note that the term customer was not used by BV themselves and the information exchange did not involve any legal or financial agreements) had different systems and wanted the data in different formats. Around 2004, BV begun to realise that this situation did not scale well and started to investigate different means to achieve a more standardised way to communicate. This initiative resulted in the implementation of a small in-house system that subsequently emerged in ways not foreseen by any of the involved actors and caused strategic changes for the organisation. It is this implementation and development process that is the focus of our study.

In our research we utilised multiple data collection approaches, including in-depth field research, ensuring that the concepts and patterns identified were grounded in the experiences and terminology of the users. This includes open-ended interviews with key BV-informants identified via the snowball technique (Churchill, 1999). Starting with the senior IT strategist, we asked for names of other persons involved in this process and thereafter interviewed them, again asking for more names in an iterative fashion. In the first round of interviews in 2008 we talked to seven individuals, whereas we in the second round interviewed six persons. When the first two rounds had been analysed, a third round of interviews were conducted to provide additional answers to questions that had emerged during the analysis. Interviewing stopped when no new names surfaced after having talked to fourteen individuals (see table 1). Between the rounds of formal interviewing we also visited BV several times and participated in numerous meetings and workshops. Whilst the formal interviews all were recorded and transcribed verbatim, our other encounters with BV personnel resulted in written field notes and a collection of organisational documents.

Informants' job titles	**Round #1**	**Round #2**	**Round #3**
Senior IT strategist	√	√	√
IT strategist	√		
System administrator I	√		
System administrator II	√		
System administrator III		√	
Account manager I	√		
Account manager II		√	√
General manager	√		
Group manager		√	
Systems developer I	√		
Systems developer II		√	
Consultant		√	
Marketing manager I			√
Marketing manager II			√

Table 1. Respondents used in this study. A snowball or respondent-driven sampling method was used to locate suitable informants.

The central challenge in working with process data, according to Langley (1999), lies in "moving from a shapeless data spaghetti toward some kind of theoretical understanding that does not betray the richness, dynamism, and complexity of the data but that is understandable and potentially useful to others" (p. 694). This is no easy task, since longitudinal case studies often generate huge quantities of verbal data. Miles and Huberman (1994) point to the usefulness of visual displays as one approach to deal with this challenge. The framework presented above was consequently used in a process where three semi-parallel flows of activities – data reduction, data display, and conclusion drawing (Miles & Huberman, 1994) – were carried out in an iterative fashion. The result of this analysis is presented below as episodes of path creation.

4 EPISODES OF PATH CREATION

Since the turn of the millennium, BV had noticed that their communication with external actors had increased rapidly. This in particular concerned train traffic information, i.e., real-time information regarding the whereabouts of the trains. This information is important to the train operators who need to update electronically the platforms signs that show passengers that train X is expected on track Y in approximately Z minutes. Since the deregulation of the Swedish railroad quite a large number of operators now exist and unfortunately they use different systems for this process and thus require BV to provide data in many different formats. BV has historically accommodated this request but around 2004 BV experienced a growing problem with all the different interfaces they needed to support. Every time a system upgrade is needed, which typically occurs two or three times yearly, there are compatibility problems with some of the train operators whose systems then received the wrong information.

The IT-development manager (who later was to become the senior IT strategist) wanted to resolve this problematic situation by harmonising the interface to a standardised one that would be shared by all involved actors. However, his ambitions reached beyond merely making the current system better in an incremental way; he envisioned a future where traffic information not only was fed to the various operators' platform signs, but straight into their back-office systems where the operators would be able to use this information for all kinds of new services. This may appear like a simple idea and rather straight-forward to implement but as we shall disclose below the involved actors had to overcome many obstacles in order to realise this innovation.

4.1 The pre-study period: A cognitive struggle

When the government in 1988 decided to separate train operation from railroad infrastructure and BV was established, BV inherited many in-house developed information systems. Whenever a system needed information from another system a point-to-point connections was typically built, resulting in a very complex environment with many cross dependencies. This way of integration has prevailed until current days. One of the developers, a long-term IT consultant, reflected upon this strategy:

> "BV has a rather old fashioned view on systems communication. If you often need data from a particular system you implement a direct connection to that system. That is sheer madness given the opportunities that exists today..."

It is thus not surprising to find that BV had many different ways of letting the train operators receive train traffic information from BV's systems. In addition to having many different interfaces, the setup was also such that BV pushed information out through these channels. The new arrangement that the IT development (ITD) manager envisioned was to innovate the current praxis where BV decided what information should be disseminated and open up for the train operators to access whatever information they saw useful, in a pull-oriented manner. The project manager, who shared this vision, explained:

> "BV must be able to distribute information not only via signs and loudspeakers, but also in a business-to-business manner. Instead of having BV sending out information concerning delays or other events, they [the operators] should be able to retrieve whatever information they need and make their own business decisions"

The above idea could not be realised by point-to-point integration since it had to allow for much greater variety and flexibility. What was needed here, according to the ITD manager, was an integration platform that would provide a single and unified interface between BV's internal systems and the external actors' systems.

However, there were much discussion between the department handling the train traffic information and the ITD manager's department. The traffic information people were preoccupied with technological matters whereas the IDT manager and the project manager tried to look at things from a

more strategic point of view. The project manager wanted BV to act more pro-actively and take a lead in this matter. He was convinced that the future involved direct communication between BV and their external partners. This vision was, however, not yet shared by the train traffic department, the project manager felt. He explains:

> "Well, it was all about signs and platform information and... signs. Very much a technical focus from their side. Where [the ITD manager] and I sat, on the other hand, there was this idea that we had to deliver information to..., well, to the customers."

Seeing this as strategic platform for the future, the ITD manager, who formally ordered the new system, and the project manager, who was a hired IT-consult, both advocated BizTalk, a commercial-off-the-shelf product from Microsoft. The rest of the organisation did not buy this idea, however. According to the ITD manager:

> "We started an investigation and had the idea that we would end up with BizTalk or something similar. [...] Both I and [the project manager] were originally of the opinion that we should go for a standard product. But later we were..., well, we were convinced otherwise [...]"

Unlike the project manager and the ITD manager, the IT development department did not envision this new system as a strategic platform and consequently considered BizTalk to be "an awful overkill", given the small amount of data the system was expected to handle. Based on the needs at the time and the estimated transaction load over the next four years, the IT development department argued – technically as well as financially – that anything but an in-house solution was out of the question.

In May 2005, following a cognitive struggle, BV formally decided to start developing an in-house solution to harmonise the interfaces between BV and its external customers, providing well-defined ways to communicate both out and in. The new system was named UTIN. BV decided to use standard protocols and familiar techniques and UTIN was consequently based on MSMQ, a message queue implementation developed by Microsoft and used as the standard communication method within BV.

4.2 The implementation period: An organisational struggle

Around 2005, BV had been engaged in a project at the European Union level, where a new communication protocol for railroad telematics was being developed. It was the TAFF-TSI (Telematics Application For Freight - Technical Specifications for Interoperability) protocol. The person representing BV in this project happened to be the ITD manager and he decided that this protocol should be used in UTIN. All these changes would affect the approximately 30 train operators and the perhaps 40 or so smaller local traffic providers who were used to receive train traffic information from BV. Previously, these actors would have a direct dialogue with BV specifying how they wanted BV to send them the data. Now, they would need to change their processes since the data would no longer be pushed. The customers would have to retrieve the required information using BV's Web Services and Simple Object Access Protocol (SOAP - a protocol specification for exchanging structured information) and the project manager wanted to include these actors in a dialogue and have them test this during the development stage:

> "We really tried to find out who would be the receiver of this information so that we could get someone to tell us whether we did the right things. Because we didn't just want to build something and say 'Here it is, come and take it'; we really had to have a receiver. Otherwise it would have been worthless".

Many of the operators showed an interest in the new system and were eager to try it but it turned out they did not have the resources to implement what was required on their side. The TAFF-TSI protocol was in its early stages and BV was the first organisation in Europe to implement it. The customers were obviously not familiar with this protocol and although there was a positive response from the operators, not many were able to take action. The ITD manager tells us:

> "Many of the smaller [organisations], they don't have the power to engage in these kind of issues at all. Small firms – say, 20 or so employees, run a small people transport business – they don't have the muscles. [...] They are all happy to comment on things once we have done something, but it is more difficult to get them engaged in the early stages."

Only some of the big actors were able to participate actively. In particular, the main cargo operator in Sweden was also engaged in the TAFF-TSI project at the European level so they were able to implement the standard on their side so that BV could test that the data was received as planned. BV benefitted from working with this company during the implementation phase since they could discuss a real use case and thus gained important information otherwise difficult to obtain. The project manager explains:

> "This was information from a real case, so we met a couple of times and it was very useful, because they described their problem with certain data, and this was good to know, so we could make things work."

Once UTIN was put in production the interests amongst the external actors grew and not only train operators showed an interest. Other actors with an interest in the railroad industry – such as ports and industries to which the railroad was an integral part of their operation – joined in. Instead of having to handle hundreds of different customers BV redesigned the way they organised themselves. The manager at the traffic information department explains:

> We arrange user meetings four times per year where we meet the train operators. We can't have individual passengers or hundreds of people at these events. There are perhaps fifteen [main actors] today, and that's about the right size for a meeting. They will have to represent their customers".

However, UTIN's account manager envisions a future where train information is made available to an even bigger audience. This kind of exposure, he believes, is likely to result in many new innovative services – from companies and individuals alike. He tells us:

> "We can't manage a infinite number of subscribers, instead we will move towards a set of..., let's call them information brokers, who can offload this from us, and handle the masses, so to say, from the individual student to small consultancy firms, and so forth. [...] We provide them [the brokers] with information and they, in turn, can maintain a large network of contacts, where they can sign deals and make money. [...] We like to see the data reach creative actors outside BV. We think much fun will happen then".

During this episode the struggles carried out were organisational in nature. The traditional way of having discussions with the customers on an individual level had to be abandoned since this format did not scale to fit the new situation that UTIN caused. Seen from an organisational dimension, the path creation process first involved moving to a few major customers who had the required resources to thereafter develop into user groups where smaller customers where represented by agents, to finally initiate the idea of external information brokers handling all the customer interfaces and possibly also do this on commercial grounds.

4.3 The launch period: A material struggle

The development of UTIN was a response to the emerging problems with maintaining individual interfaces for every customer. A central design feature for the new system was thus the standardisation of communication. The capability to handle a larger span of information types also opened for new user groups and UTIN was therefore also designed with flexibility in mind, when it came to the administration of customer accounts. According to the UTIN account manager this works fine:

> "[UTIN] was made as general as possible so that it is no big deal adding or removing customers from it. It's just a minor configuration and it's done, it's very quick."

One of the new information types handled by UTIN was Radio Frequency Identification (RFID) data. This information was collected from tags mounted to the railroad cars and relayed to the car owners via UTIN. However, the BV developers working with RFID data were not satisfied with the functionality of UTIN, which they found not flexible enough for their needs. In addition to sending certain data entries they also needed to send entire files, and this was not part of the original design idea it was not supported. Another limitation was that UTIN had no options for data filtering. People in the RFID project wanted to be able to select only tags with a certain customer ID. If only 5 cars in a train set belong to a customer, they do not want to receive data from all 30 cars. To allow for this the RFID developer had to build a separate system that would do the filtering prior to sending the data to UTIN. This, however, meant that the customer database had to be duplicated; it had to exist both in UTIN and in the filter system and the two had to be in synch. Adding and removing customers may have been easy and flexible but specifying exactly what each customer should have access to was quite awkward.

In a response to the lack of flexibility in UTIN, the RFID developers have started a parallel under-the-radar development, where they instead use BizTalk. There have been a number of attempts to get BizTalk up as an officially supported service, the developer tells us, but they have all failed. His explanation is that no unit wants to end up with the cost for this investment. The RFID developer has circumvented this problem by forming an alliance with the IT operations department, to get the hardware, and using his own personal Microsoft licence, to get the software. He explains:

> "BizTalk has not been used at BV previously, so we're some kind of pilot project. We have just established a joint venture with operations so they have provided us with a server. And I have one of those msdn licences from Microsoft to be used for testing and such. So we've been able to install BizTalk and test it for free – for a limited period of time, obviously".

So the original decision to dismiss the platform idea and go for an in-house system is now challenged. When the concept was implemented and put to test it did not live up to the expectations and technical work-arounds were starting to surface. Returning to the idea of an off-the-shelf solution, the RFID developers asked for the added flexibility that a commercial product would offer. However, having tested BizTalk for some time the organisation learnt that it was difficult to accommodate everyone's wishes, even with a commercial tool. Although a broader array of data formats were supported, the developers still could not filter data the way they wanted. One developer explains:

> "I'm actually quite disappointed with BizTalk, too. I have discovered that it is too very static so that you must... so that the filters you can define in BizTalk are very limited. [...]"

In this episode we see that when UTIN is put in production in 2007 many different actors, internal as well as external, start to use it and soon they realise that their needs are not met. Greater flexibility is asked for, both in terms of other data formats and possibilities to filter data with higher granularity. Understanding the struggle from a material dimension, the developers in the RFID project resolves the conflict by semi-official skunkwork; they develop a parallel solution using BizTalk – a solution the organisation rejected a couple of years earlier.

4.4 The usage period: A cognitive struggle

Since UTIN's primary objective was to deal with train traffic information, the ownership of the system therefore ended up in the train traffic information department. This follows from a long tradition within BV to place the decisions and the responsibilities for systems near the part of the business that requested them rather than to place the centrally. There have been a few reorganisations within BV over the years but UTIN has pretty much stayed were it first started and UTIN's account manager thinks this is a proper location. His manager agrees and tells us:

> "We don't know what the organisation will look like in the future but as it is now I think it [UTIN] is properly placed. I see it as an output channel the same way as signs and loudspeakers. It is a way to disseminate information; it's one of our out-channels for traffic information."

Although this was initially how UTIN started, its role has shifted significantly over time and other BV actors have come to see it entirely differently. In the RFID project, they think of UTIN more as an integration platform and as such it should not be managed by the traffic information department. One of the RFID developers elaborates:

> "It feels more like a basic service, like an SQL server or a Web server or something, so it should be with Operations, I think. That way developers and different projects could say that we like to put our application on your server. So it should be with Operations; it's unnecessary for every project to set up their own enterprise server".

When asked whether he thought that UTIN now was placed correctly in the organisations, the IT strategist hesitates:

> "Dangerous question today... [pause]. No. Well, UTIN is yes but the integration platform is no. So many things are happening right now, and in the future organisation this is an important strategic function. So, I think we will see some changes here in the future. [...] Otherwise, it would surprise me…, I mean, the need is present is so many different areas..."

As the IT strategist implies in his answer above, the question of where in the organisation to place the ownership of the system is linked to the mental model people have of what kind of system UTIN is. UTIN: the-interface-towards-train-traffic-information is placed where it should be but UTIN: the-strategic-integration-platform should be placed somewhere else, according to the IT strategist.

But at the traffic information department, they see UTIN strictly in its original role as a provider of traffic information. When discussing UTIN from a larger perspective, the department manager says:

> "Maps and other files *could* be sent. Documentation, policies and things like that. It might be useful for the train operators or for the entrepreneurs working with the railroad, they might want it. But this isn't traffic information and if we were to start using UTIN as some sort of file-sharing device it would be wrong. It's not the objective for this system".

The debate regarding where to place the UTIN ownership could be seen as an organisational struggle but we argue it is more a cognitive struggle. While the traffic information staff remains true to their original mindset and see UTIN as a channel for train information, other actors such as the IT strategist and the RFID-developers re-design the conceptualisation of UTIN to accommodate a broader vision.

5 DISCUSSION

We have accounted for an innovation process that has unfolded at the Swedish Railroad Administration (BV) over the last six years. The initial vision was to innovate the communication process between BV and the train operators as far as train traffic information was concerned. Applying a theoretical framework of organisational tensions and multiple design structures as suggested by Henfridsson et al. (2009) we have analysed the process and illustrated that it was far from straightforward. Our study differs in two aspects from Henfridsson et al.'s study. Firstly, it is more micro-level. We studied fewer individuals during a shorter time span, thus working with down-scaled contradictions. Secondly, we have studied a more heterogeneous set of actors, thus exposing ourselves to the more diverse set of identities that Henfridsson et al. suggest exist in contemporary organisations.

One of the contributions of the framework suggested by Henfridsson et al. (2009) is that it stresses the complexity of path creation as it affects multiple structures. Henfridsson et al. explain that innovation occurs across different *layers* of design. Although we appreciate and add empirical support to the multi-dimensional aspect of innovation, we find the notion of layers somewhat problematic, as it connotes a hierarchical relationship. Layers are typically used when describing a sedimentary structure where new layers are added on top of older ones, assuming a *temporal* dependency. Further, when used metaphorically in information systems research, layers are often used to illustrate an architecture where more fundamental layers found at the bottom offer services to the more high-level layer above,

suggesting a *functional* dependency (cf. Hale, 1997; Braa et al., 2007). We find neither to be the case in the episodes of path creation that we have accounted for above, and we argue that layer thus is a misleading description. Instead, we suggest that material, cognitive, and organisational should be understood as three interrelated and complementing *dimensions of design*. We posit that IT-based innovation is better understood when it is not simply thought of as a redesign of the IT-artefact (i.e., the *material* dimension), but as a reconfiguration of dominating *cognitive* and *organisational* structures as well. Figure 2 illustrates how the focus has criss-crossed between the three design dimensions and pin-points the conflicts that have been identified.

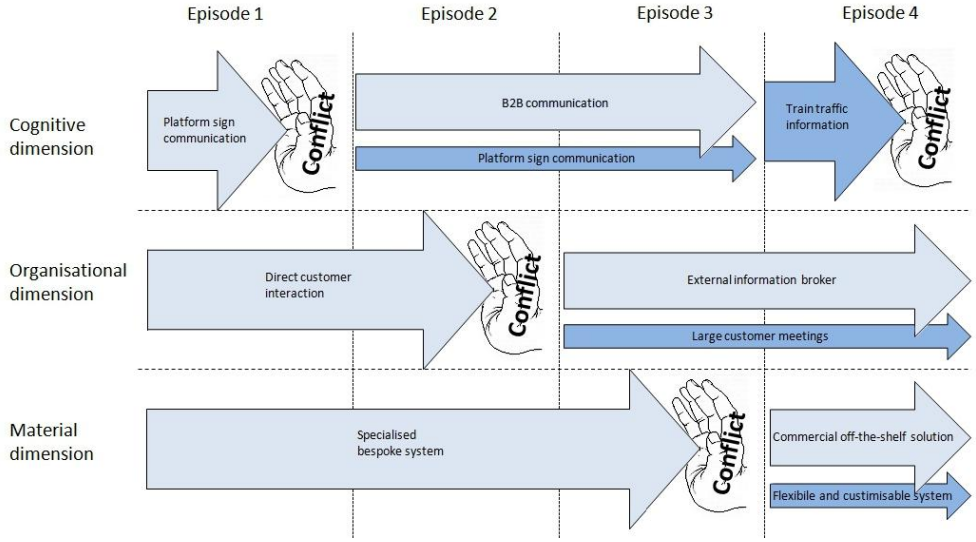

Figure 2. Path creation seen from multiple dimensions. A dominant path gives way to an emergent path whilst a residual path remains passive in the background

The first episode focuses on the cognitive dimension as the dominant understanding of customer communication as merely platform sign updates clashed with the idea of a broader business-to-business solution. This can also be described as a conflict between the old point-to-point integration model and the idea of an integration platform. The IT strategist and the project manager tried to deviate from the old path but the IT development department managed to convince the project that a platform solution such as BizTalk solution was neither wanted nor needed. The strongest argument seems to have been the financial aspects, were BizTalk came with an explicit price tag whereas a home-made and down-scaled solution arguably would be cheaper – at least in the short run. The IT strategist and the project manager did however manage to sell the idea that the new solution should go beyond merely updating platform signs at the train stations, and have a broader scope. It is quite obvious, though, that the conflict was not fully resolved as the organisation as a whole did not embraced the new mental model. Many continued to think in terms of "platform signs" and the cognitive conflict was merely pushed backstage as a residual structure, to use Henfridsson et al.'s notation, to resurface as a new cognitive struggle in episode 4.

Switching focus to the organisational dimension, the next conflict that surfaced was when the interest in UTIN exceeded BV's expectations. The new train traffic information users rapidly became too many, making it impossible for BV to deal with them directly, on an individual bases. This situation was not something that the IT strategist or the project manager had envisioned during the pre-study. The path that started to emerge was to outsource customer relations to an external information broker, an insight that grew out of the problems experienced during the implementation phase. However, as a residual structure BV continued to deal directly with some of their customers. These were all larger organisations that were thought of to act on behalf of their customers and partners, in what can be described as a pre-phase to information brokering.

In the third episode, a conflict at the material layer surfaced as the UTIN was put in production and thus exposed to the organisation and their live business needs. The down-scaled and more narrow-in-scope home-made solution that the IT development department successfully had advocated was now challenged in favour of a more general purpose platform product. The RFID developer, who actually was a contracted consultant, had previously attended a Microsoft BizTalk course and therefore had a private test licence that he could use to set up a pilot environment without having to buy the product. He thus circumvented the main reason for not using BizTalk; its high cost. By deviating from the established UTIN path and showing a proof of concept with BizTalk, it is likely that he paved the way for future BizTalk solutions. However, even BizTalk was considered too rigid and too difficult to customise by some organisational member. The idea of an ideal system that could be custom-made to fit exactly the demands of the developers, continued to exist as a residual structure.

Finally, in the fourth episode we again came across a cognitive conflict as the ownership of the solution was questioned. Depending on whether one conceptualises UTIN as merely a channel for traffic information or as a platform for general information interchange the organisational issues becomes rather different. Although this conflict on the surface relates to organisational issues, we argue that is in fact a cognitive struggle resulting from the fact that the ideas of UTIN as merely a traffic information channel that we saw in episode 1, continued to exist as a residual structure. This conflict now re-surfaced, causing the organisation to question the logical home of UTIN. Is it to be understood as a dispatcher of train information or should it be conceptualised as a strategic information sharing platform?

Using the above framework to analyse a tight group of design engineers at CarCorp, Henfridsson et al. (2009) argued that path creation was a cyclic process that played out on what they referred to as different design layers. Organisational contradictions at the material layer forced the engineers to modify their mental models. This modification caused contradictions at the cognitive layer which made them shift their attention to the organisational layer. Although Henfridsson and colleagues do not say so explicitly, their figures seem to suggest that the design layers are traversed in a particular order: from material via cognitive to organisational in a sequential manner. As our story illustrates, this process can also take on a different pattern. We argue that this observation is important since it meant that the path noticed by Henfridsson et al., i.e., material to cognitive to organisational, should thus not be understood as *the* path. By offering a second and somewhat different view of path creation, our study lends additional empirical support to Henfridsson et al.'s theory that path creation in IT-based innovation is a multi-dimensional activity. Having this in mind would allow researchers and practitioners alike to understand better this complex process and be able to act more proactively. This is the important lesson to take away from this study.

6 CONCLUSIONS

We have empirically studied a case of IT-based innovation at the Swedish Railroad Administration. A new IT system – UTIN – started out as a train information system for train operators, i.e., rather limited in scope and limited in its customer base, but as a result of mindful path creation grew towards a strategic information platform for the whole railroad industry, i.e., extended in its scope and extended in its customer base. The development process was far from streamlined and took many unexpected turns as new paths were created as a result of various forms of struggles or conflicts. Although this was an IT-based innovation where a new artefact was being developed, we have showed that dimensions other than the purely material one have to be considered in order to understand how innovations unfold.

A lesson for practitioners and researchers alike is that IT-based innovations cannot be fully understood from the material design perspective only. A one-dimensional focus on the artefact *per se* may result in a prolonged struggle that will not be resolved until looked upon from a cognitive or organisational dimension. The inclusion of all these three dimensions from the outset may therefore lessen the friction involved in IT-based innovation projects.

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