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Calculations Sparking Innovation Development

A case study investigating the role of accounting calculations in innovation processes within socio-technical systems

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ABSTRACT

This thesis explores the use of accounting calculations in innovation processes during socio-technical change. While previous research has elaborated on accounting's role in innovation development within single organizations, limited focus has been given to accounting calculations' role in large systems, often referred to as socio-technical systems. Through a single in-depth case study, we develop a theoretical framework drawing on concepts of transition theory to analyze how accounting calculations were used during the development of an Electrified Road System for Swedish heavy-freight transportation. The study finds that accounting calculations enable, constrain and shape innovation development within the socio-technical levels. While confirming several previous findings within the research domain, we add to the insufficiently investigated discussion of how accounting help shape the development trajectories of innovation. In the case of TranSys, we find that accounting calculations shaped the development trajectories of innovation towards incremental innovation characteristics.

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1. Introduction

"If we are to achieve the climate goals within the transportation sector we have to step away from fossil fuels. This is a condition if we want to continue to have today's society"
(Business Developer B, RoadCo)

During the last ten years, the pressure on organizations and actors within society to decrease their negative impact on the environment has increased dramatically. Culminating in the recent Swedish climate law of 2018, the pressure is on for these parties to make changes in how they operate. As of today, organizations are struggling to identify business-viable and environmentally friendly technologies for their operations. Hence a key factor in recent years, and most importantly going forward, is the development and commercialization of new innovations.

As the role of accounting in society has evolved from being viewed as purely book-keeping to a powerful enabler in change efforts, the research on its role in innovation activities has increased. From early studies where accounting was viewed as inhibiting development processes (Abernethy & Brownell, 1997; Birnberg, 1988; Brownell, 1985), the research field has evolved to now identifying accounting as an enabler and shaper of development trajectories (Bisbe & Otley, 2004; Mouritsen et al., 2009; Christner & Strömsten, 2015).

More recent research has focused on the use of accounting calculations in innovation processes. Mouritsen et al. (2009) showed how accounting calculations may be used as short- and long translations, enabling a sense of the whole. Revellino & Mouritsen (2015) characterised accounting as an engine driving innovation forward. They argued that accounting calculations shape the development trajectories of innovation by triggering a mobilisation of knowledge and insight, which later become part of the innovation. In a second research article, Revellino & Mouritsen (2017) revisited their previous case company and identified how calculative instruments of both accounting and innovation co-developed in a dynamic way, resulting in the creation of additional value beyond the scope of the initial process. Christner & Strömsten (2015) argued that the notion of accounting calculations as enabling or constraining was non-binary, and that the enabling of one development trajectory resulted in the constraining of alternate courses of action.

In their concluding discussion, they state that their case company was part of a socio-technical system and call for more research on how accounting calculations are used in that context.

With this paper, we answer the call by Christner & Strömsten (2015) regarding further research on the concept of socio-technical systems. Our case, TranSys (anonymized), is a system of actors within the Swedish transportation industry and we follow the innovation development of an Electrified Road System (ERS). We draw from transition theory and characterize TranSys as a socio-technical system currently undergoing socio-technical change. We aim to expand the current literature on the role of accounting calculations in innovation in two ways. First, we acknowledge that recent research concludes that accounting calculations shape the development trajectory of innovation, but more research is needed on *how* this manifest itself. Second, we investigate the case of TranSys to explore how accounting calculations are used in the setting of socio-technical systems, which has not been the focus in previous research. To conclude, this paper aims to answer the following research question:

How do accounting calculations shape innovation development trajectories in socio-technical change?

This study finds that the use of accounting calculations in socio-technical change confirm several of the current findings within the research domain. However, our theoretical framework highlights how accounting calculations were used differently within the respective levels of the socio-technical system. Further, we argue that the use of accounting calculations within socio-technical systems shape the development trajectories of an innovation towards more incremental innovation characteristics.

2. Theoretical Foundation

Section 2.1 provides the historical development of the research domain as well as the more recent developments within the field. We provide an overview of transition theory and the concept of socio-technical systems in 2.2 and thereafter present our developed theoretical framework in section 2.3.

2.1 Domain Theory

In management accounting literature, the role and characteristics of accounting with regards to *innovation* have been studied from numerous angles and perspectives. As a result, the terminology used is often quite broad and loosely defined. For the purpose of this thesis, we focus on how management accounting, and more specifically management accounting calculations, are used in the context of innovation development.

2.1.1 Management Accounting, Innovation and Methods of Control

When reviewing accounting research within the field of innovation development, management accounting has often been associated with the notion of control. Initially, formal control systems where assumed to be dysfunctional in such settings (Rockness & Shields, 1984; Abernethy & Brownell, 1997), as it was deemed as constraining or irrelevant in innovation and research and development (Birnberg, 1988; Brownell, 1985). Abernethy & Brownell (1997) argued that certain task characteristics were not well-suited for accounting-based controls and instead advocated the use of non-accounting controls, such as personnel forms of control. This was a response to earlier streams of research advocating non-accounting controls in order to achieve effective control when the setting differs from that of manufacturing (Abernethy & Stoelwinder, 1995; Foster & Gupta, 1994). Ouchi (1979) argued that clan controls should be preferred over formal control mechanisms in research and development settings. Others claimed that social controls would provide the autonomy needed to allow employees to innovate in complex and uncertain settings (Tushman & O'Reilly, 1997). Brown & Eisenhardt (1997) built on the need for less autonomy, and further defined the activity as a balancing act. There is always need for structure, but it should be limited to balance the freedom to innovate. If the balance is not successfully achieved, the result is either no change at all or chaos (Brown & Eisenhardt, 1997). Searching to enable this balance, Kamoche and Cunha (2001) proposed the minimal structure framework, which comprised both a technical and a social structure for the control of product development projects.

As outlined above, much research concerns itself with how to enable the creativity needed for innovation. Although historically linked with its rationalization capabilities, which were seen as incompatible with the creativity needed for innovation (Raelin, 1985), certain forms of management control have been deemed to provide a context in which creativity and innovation can be stimulated (Bisbe & Otley, 2004; Chenhall, 2003; Ditillo, 2004). Bisbe and Otley (2004) analysed the Levels of Control framework developed by Simons (1994) and provided evidence against the suggestion that a more interactive use of formal management control systems correlates with innovation. In contrast, other streams of research argue that management control may constrain the motivation needed for creativity and innovation (e.g. Dunk, 2011; Adler & Chen, 2011). The research focus on creativity also manifests itself through the settings that historically have been chosen for research. Management accounting literature is more concerned with the role of management accounting in settings where innovation is particularly relevant, e.g. knowledge-intensive firms (Bisbe & Otley, 2004; Brown & Eisenhardt, 1997; Davila, 2000; Ditillo, 2004; Hansen & Jönsson, 2005; Jorgensen & Messner, 2009).

Drawing upon more recent studies, there are conclusive evidence that management accounting does support innovative courses of action and innovation development. This has been highlighted in various ways. Management accounting has been stated to support innovative courses of action when it is used as enabling systems (Ahrens & Chapman, 2004; Widener, 2007). Additional to enabling, the notion of interactive use as described in the *Levers of Control framework* by Simons (1995) has also been defined as a management accounting configuration that supports innovation (Bisbe & Otley, 2004; Bisbe & Malagueno, 2009; Simons, 2005), as accounting is facilitating the creation of dynamic tensions through both the enabling and controlling roles of management accounting (Mundy, 2010). The innovation context, it seems, has been proven to render accounting a tool for creating learning spaces (Bisbe & Malagueno, 2009; Bisbe & Otley, 2004; Davila, 2000; Mundy, 2010). This highlights how one of the outcomes of innovation activities is the learning process that the participants are forced to go through. The studies mentioned above are indications of how accounting may facilitate a greater learning process by reducing the complexity and ambiguity of innovation.

Management accounting calculations are closely related to the concept of management control systems and are often bundled together in research. Therefore, a closer definition of management accounting calculations is needed going forward. In research literature, accounting calculations have been attributed many characteristics and capacities. As inscriptions that produce knowledge (Robson, 1992), accounting calculations have the capacity to create visibility (Cooper, 1992), mediate between complementary resources (Miller & O'Leary, 2007) and identify objects and objectives to be managed (Chua, 1995; Miller, 2001; Vaivio, 1999). Robson (1992) concurs with Cooper (1992) in that accounting calculations develop visibility, but it also creates organizational time and space. He analyses how accounting calculations enable the mobilization of distant places and make them part of managers' worlds. In general, management accounting calculations provide substantial amounts of knowledge that is available to management (Cooper, 1992; Law, 1996). Management accounting calculations are intricately related to organizational practices, and two main relations have been expressed in research. Either it may be related to individual managers' localized embedded decision-making (e.g. Ahrens & Chapman, 2004, 2007), or through relation to change initiatives with focus on managing the employees and transform the company (e.g. Ezzamel et al., 2004; Miller & O'Leary, 1994).

Organizations and markets may be brought forward and made visible by management accounting calculations, by example through calculations concerning revenue or development in profitability (Hines, 1988; Quattrone & Hopper, 2005). Calculations have been said to impose an agenda that requires a response (Miller, 2001), and in the context of innovation, help transform the effects of innovation from more technical to economic (Davila & Wouters, 2004; Hansen & Jönsson, 2005). Several studies also point to the fact that calculations serve in a competitive space. For example, Mouritsen et al. (2009) found that if managers do not follow the prevailing calculation, they had to make an additional calculation to make their point. In order to combat one calculation, another one was needed (Mouritsen et al., 2009). This indicates that one may attribute various degrees of strength to accounting calculations as they compete for attention. Sometimes accounting calculations may not work because of the presence of stronger calculations (Mouritsen et al., 2009). Due to the competitive nature of calculations, Callon (2010) found that there may be counter-performativity or misfire. The notion of accounting as performative, deployed by

Mackenzie (2008), suggests that it influences managers', companies' and institutions' practices (Ezzamel et al., 2012; Mouritsen et al., 2009; Vosselman, 2014).

2.1.2 Accounting Calculations Shape the Development Trajectories of Innovation

Christner and Strömsten (2015) argued that, while previous research has shown that accounting may enable product innovation, more details of how this actually manifests itself is needed. They studied the role of accounting calculations in the development of a biotech innovation, examining the case company through three very distinct stages of the development process (in the hands of the scientific founders; commercial company owned by a Venture capital firm; listed on a stock exchange). The study showed how different accounting calculations were used through each of the distinct stages, but more importantly that calculations helped shape the development process (Christner & Strömsten, 2015). This showed how the concept of constraining/enabling is not binary, as the enabling of one development trajectory resulted in the constraining of alternative courses of action (Christner & Strömsten, 2015).

Mouritsen et al. (2009) used three examples of management accounting in innovation to show that management accounting calculations not merely describe the properties of innovation, but in fact adds perspective to them through the mediation between innovation-specific concerns and firm-specific concerns. The authors explained this by the notion of short and long translations. They define short translations as when management accounting calculations encourage either extension or reduction of innovation activities by proposing performance to be adequate or inadequate. In contrast, long translations mobilize multiple calculations that problematize the role of innovation for corporate purposes differently (Mouritsen et al., 2009). This suggests that accounting calculations may enable a "sense of the whole", which could enable certain key characteristics of innovation (Mouritsen et al. 2009).

Revellino and Mouritsen (2015) studied the relationship between calculative practices and innovative activities through the case study of *Telepass*, an innovation enabling automatic toll collection on Italian motorways. They further strengthened the notion of accounting being not only a tool for innovation processes, but an integral part also affecting its development trajectories. By deploying the concept of accounting as an engine (MacKenzie, 2008), they showed how

calculative practices triggered a process of mobilization of knowledge and insight which became part of the innovation (Revellino & Mouritsen, 2015). In a second research paper on the case of Telepass, Revellino & Mouritsen (2017) further discussed how accounting calculations can produce effects beyond the intentions and control of actors. They stated that the calculative instruments of accounting and innovation co-developed dynamically and combined created value beyond the initial scope of the process. Linking to the case of Telepass, this was manifested in how the introduction of automated toll collection also resulted in safety improvements and environmental preservation (Revellino & Mouritsen, 2017).

When studying accounting in the context of development processes, many researchers have defined the role of accounting as that of mediating instruments (Miller & O'Leary, 2007). Mediating instruments refer to instruments that may connect and mediate between discrete domains and dispersed actors, which in the case of Miller & O'Leary (2007) was used to frame capital spending decisions of individual firms with investments made by other firms within the same or in similar industries.

While many of the empirical accounting studies have examined product development and innovation initiatives within specific organizations, we want to focus on innovation initiatives involving various parties who are all part of a larger system. It is worth clarifying that we do not wish to investigate the concept of inter-organizational control, such as the study conducted by Meer-Kooistra & Scapens (2015). They focused on the occurrence of inter-organizational co-development projects and the control activities between actors. The focus of their study was temporary organizations, meaning that each actor has the possibility to go their separate way after the project. Instead, we aim to explore the research calling from Christner & Strömsten (2015), who urged for more research concerning accounting's role in innovation in *socio-technical systems*, i.e. large systems of actors constituting a societal function. Hence, we aim to answer the following research question in our thesis:

How do accounting calculations shape innovation development trajectories in socio-technical change?

2.2 Method Theory

To explore this nascent area of accounting research, we let our initial empirical data guide us in forming an appropriate theoretical framework. The initial findings showed how accounting calculations were used in different contexts depending on the actor. In order for us to understand the socio-technical system we not only took the incumbent system into consideration, but also the socio-technical system that was emerging. To facilitate an analysis in the context of accounting and innovation, we drew upon concepts within transition literature. This enabled the breakdown into separate levels of the emerging socio-technical system, which we leveraged in our analysis.

2.2.1 Socio-Technical Systems and Socio-Technical Change

In *Networks of Power*, Hughes (1993) established the foundation for socio-technical systems and socio-technical change by examining the process and implications of the electrification of western society. The concept of systems, which is the foundation of this thesis, has been used in several fields of research but is sometimes vaguely treated or defined. For the purpose of this thesis, the system concept was used in a broader and more soft approach, meaning that social and technical dimensions was considered to be intertwined forming socio-technical systems (Bijker, 1997). A large technical system for example concerning transportation, indicating that it is based on artifacts, is often described as a socio-technical system and thereby defined by its function (Geels & Kemp, 2007). Building on this concept is socio-technical change, which may be defined as a set of processes that changes the incumbent socio-technical configuration. Socio-technical change is the platform that may enable socio-technical transition. Transitions could take place over many years, involving processes in which "new products, services, business models, and organizations emerge, partly complementing and partly substituting for existing ones" (Markard et al. 2012, p.2).

In traditional innovation literature, a key distinction is made regarding the nature of innovation. The first form, *radical innovation,* is described as fundamental or revolutionary change (Dewar & Dutton, 1986), but has also been defined as breakthroughs or clear departures from existing practices (Anderson & Tushman, 1990). A key aspect is that it builds on previously unfamiliar knowledge (Macher and Richman, 2004). The second form, *incremental innovation,* is a contrasting case as it builds on currently existing knowledge and technologies but improves and broadens the applicability and potential (Gatignon et al., 2002). Leifer (2001) found that the lifecycle of radical innovation projects differ substantially from those of incremental innovation,

as they are filled with uncertainties and discontinuities. Although the concept of radical and incremental innovation has been frequently used in accounting research literature, the distinction is seldom analyzed (Revellino & Mouritsen, 2015).

In socio-technical change, the variables of innovation merge with external pressure exerted on the socio-technical system. In order to elaborate on accounting calculations' role in this context, we argue that we must analyse the dynamics between the incumbent system and the emerging system and incorporate the dimension of external pressure. Therefore, we chose to deploy the Multi-Level Perspective framework.

2.2.2 The Multi-Level Perspective (MLP)

The multi-level perspective is a theory that conceptualizes overall dynamic patterns in socio-technical transitions (Geels, 2011). As a conceptual framework, it is often used in sustainability transition literature to describe and analyze the dynamic processes occuring during a socio-technical change (Geels, 2005; Markard et al., 2012). It suggests that socio-technical transitions happen through the interplay of multiple developments at three levels: socio-technical regimes, socio-technical landscapes and technological niches (Tongur & Engwall, 2017). First, the *socio-technical regime* level represents the established practices and rules (Geels, 2005, Rip & Kemp, 1998). This is the incumbent system and is characterized by stability and is comprised of stakeholders that produce and maintain the incumbent system through formal (*regulations and laws*), normative (*roles and norms*) and cognitive (*beliefs and principles*) rules. The socio-technical regime also consists of the material, both tangible and intangible, that are part of the system. Second, the *socio-technical landscape* level, which implies the broader perspective in which the socio-technical system is active. It represents the wider external environment and events that regime actors cannot influence directly, but rather must respond to. For example, such events could include natural disasters or war, but also policies and regulations. Third, the *technological niche* level is what has been referred to as the locus of innovation (Geels, 2005), and it constitutes where the actual innovation takes place. The new products and practices that are developed in the niche are protected from forces of the main market selection environment as it is presumed that *"path-breaking innovations fail to successfully compete within selection environments embodied*

in incumbent socio-technical regimes" (Raven & Smith, 2012, p.1). This allows for learning processes that could lead to novel technologies, structures, and behaviours (Schot & Geels, 2010).

According to the MLP-framework, the socio-technical regime must change in order for the system as a whole to change. Changes, often referred to as socio-technical transitions, can only occur by external *landscape pressure*, meaning that the dominant socio-technical regime is destabilized through external pressure such as climate change. External landscape pressure, in combination with local niche innovations, can then create a window of opportunity that allows for emerging niche innovations to break through (Geels & Schot, 2010).

The Window of Opportunity concept (W/O) is a significant feature within the discourse of socio-technical transition (Geels, 2002; Smith et al., 2010) and the MLP-framework. It represents a situation in which *"an established socio-technical regime becomes unstable due to external factors, or internal problems, creating opportunities for alternative technologies"* (Tongur & Engwall, 2017, p.84). As a temporary phenomenon, a window of opportunity is a specific period where an usually stable institutionalized regime becomes receptive to innovation. It leaves the system temporarily open to influence from alternative technologies, resulting in the potential for the system to shift from its established trajectory to facilitate innovation (Unruh, 2000).

Normann (2015) discussed how a window of opportunity does not lead to change by itself. A window of opportunity emerges when a problem produces a temporary crack in the regime, but these cracks may sometimes be repaired by the existing regime actors. As mentioned before, existing regime actors often have a large invested interest in the current socio-technical regime and will go to lengths to maintaining the status quo. Transition will only occur when there is a common link and the three levels reinforce each other (Van Driel & Schot, 2005). If no plausible solution emerges within a reasonable timeframe during a window of opportunity, it will close and lead to a restabilization of the existing regime (Normann, 2015).

2.3 Theoretical Framework

As described in section 2.1, the role and importance of accounting calculations in innovation has been of academic interest for many years. Accounting calculations can serve both as an enabler of

innovation, providing structure through space and time, facilitating learning and by creating dynamic tension, as well as a constrainer of innovation by imposing control and quantification which can suffocate creativity. This dynamic role of both facilitating and hindering innovation has been shown to influence and shape the development trajectories of innovation within organizations. It can hence be concluded that accounting calculations and change are closely intertwined.

Societal concerns, such as environmental issues, are forcing organizations to respond. Additionally, the issues are also resulting in society questioning current courses of action. This results in extensive pressure on systems to change and adapt. Accounting's part in this context is unclear as there is a gap in current research as to if, and how, accounting can play a role in socio-technical change. Socio-technical change, sharing many of the characteristics with innovation development within single organizations, distinguish itself by involving a vast number of separate actors pressured by the wider context, creating an intricate web of relations and motivations. Also, as many of the most pressing challenges in current society revolves around socio-technical systems, an exploration and clarification on how accounting may play a role in such a setting is of increasing interest. To build a solid analytical lens, we have incorporated several key characteristics from research on socio-technical systems in our theoretical framework, which in combination with current research about accounting calculations' role in innovation, enable us to explore accounting calculations' role in the new context of socio-technical change.

By deploying the Multi-level perspective framework for socio-technical change we aim to highlight how the use of accounting calculations manifests itself on the different levels of socio-technical systems during a potential *window of opportunity*. As described above, the MLP framework enables a dichotomization of a socio-technical system into separate *levels*. These levels are not ontological descriptions of reality, but in the context of socio-technical change, they work as heuristic and analytical concepts that facilitates understanding of the complex dynamics that are present during a possible transition. To fully comprehend this new perspective on accounting calculations' role in innovation development processes, we also had to examine the nature of the innovation fueling the transition, another nascent research area. Figure 1 describes our established theoretical framework, which will be deployed both in our empirics and analysis.

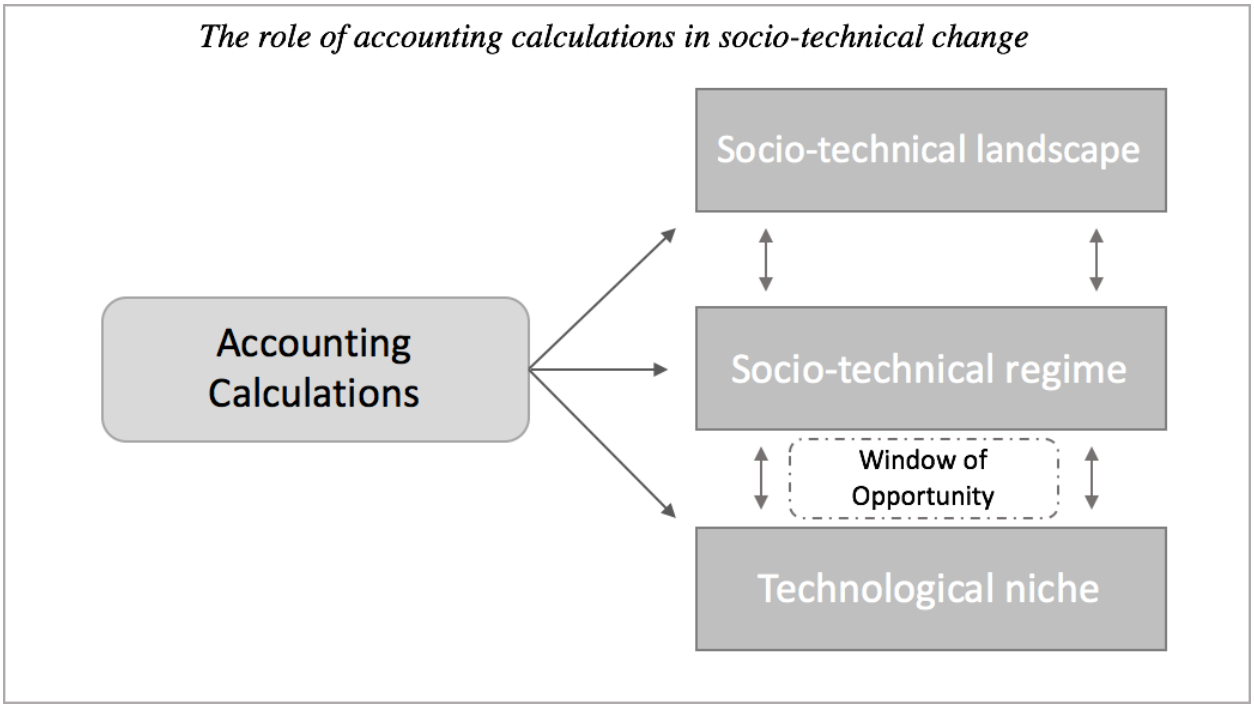

Figure 1: The role of accounting calculations in socio-technical change

3. Method

This section presents the research method selected for our thesis. 3.1 describes the research design of this paper, 3.2 elaborates on our data collection process, 3.3 expands on the analytical process and 3.4 investigates the validity and reliability of our thesis.

3.1 Research Design

3.1.1 Empirical Method

This thesis was designed as a qualitative single in-depth case study. Merriam (1994) concludes that the benefits of a case study is that it enables the researcher to explore the complexity of organizational dynamics, different perspectives to it and the factors affecting it. The main distinction from the majority of qualitative research within the field of accounting is that our "case" is in fact a socio-technical system. Hence, the complexity of organizational dynamics is in our case the complexity of system dynamics. This should potentially increase the level of different perspectives as each actor is part of a separate organization with specific culture, goals and agenda, therefore further motivating the use of a qualitative study. Previous research regarding accounting calculations' role in innovation development has mainly focused on a firm-specific or industry-specific perspective, which makes the topic of this thesis an insufficiently researched area of the research domain and suitable for the approach of a qualitative case study (Merriam, 1988). Due to the partially unexplored nature of the research setting, we chose an open-ended research question that Edmondson & McManus (2007) argue is the recommended practice as it helps shape the researchers' understanding of the subject at hand.

The objective for this case study was to understand how the use of accounting calculations, between the actors in a system, affects the development trajectory for an innovation. In order to investigate this phenomenon, we needed to understand how accounting calculations were used both internally and externally, and the different interpretations that occurred. The *how* thus played a significant role in this thesis, which also was an argument for the qualitative case study approach (Yin, 2014)

As described in our theoretical framework, the understanding of a system is contingent on observing and analyzing as many actors as possible. The system is made up by, and constantly evolves through, its actors, which motivated the choice to maintain the scope relatively broad. The

choice to maintain a relatively broad perspective also enabled a deeper understanding through interviews, observations and analysis of several different actors. Moreover, the ability to gain an understanding of the dynamics of a particular case setting is improved by the use of interviews, observations and various documents (Eisenhardt, 1989).

This thesis was conducted as a single-case study, although research suggests that multiple-case studies offers more robust and generalizable results as it is based on a more varied empirical ground (Eisenhardt & Graebner, 2007). The reason for this was partly due to the limited scope that characterizes a master thesis, but also due to the nature of our research question where several variables and multiple forms of evidence are of interest to us, which Yin (2014) claim an in-depth case study is well suited for. Further, the circumstances of this study make the phenomenon and the context of the phenomenon highly influential on one another. Dubois and Gadde (2002) conclude that in-depth case studies best understand this interaction as they provide a holistic view of the object in question which was particularly paramount for us as the object of this study had some unusual characteristics.

3.1.2 Selection of Case System

When writing about systems, localizing suitable case objects is challenging in two ways. First, the fact that a system is constituted by many different actors suggests that the level of ownership might be blurry. A qualitative case study requires broad access in order to be able to find and analyze relevant data. When actors themselves might not be fully committed to a project, as it is in collaboration with other actors, the willingness to grant access for external parties might be lower. Second, there is a challenge of mapping and working through the system. A system may be loosely defined with many actors with a varied degree of involvement. Therefore, identifying who to focus on and facilitate interview opportunities may be troublesome.

After discussing various research topics with our thesis tutor, he facilitated the contact with TranSys. Through an initial interview with the Project Manager we were able to gain access to many different actors within the system. The attributes we found interesting were that TranSys included actors from different parts of both the current value chain and the potential future value chain. By observing how these actors worked together to commercialize an innovation involving

electrified road transportation, we aimed to elaborate on accounting calculations' role in socio-technical change.

3.1.3 Research Approach

The thesis process was conducted using the abductive approach of systematic combining (Dubois & Gabbe, 2002). An abductive approach represents the middle ground between a deductive approach, where the empirics are developed by the theory, and an inductive approach, where the theory are developed by the empirics (Bryman, 2015). In systematic combining, the theoretical framework and the empirical findings are continuously developed and adjusted throughout the study (Dubois & Gabbe, 2002). This enabled us to adopt a nonlinear, iterative process were interview guides, hypotheses and frameworks could be developed and elaborated on alongside our empirical findings. Also, while the structure of the incumbent system was clearly visible, the design of the emerging system was not. Actors had different views of what the new system should look like, which meant we had to continually adapt our scope. Initially, the thesis had a focus on the core transportation chain and the parties involved, but the final focus also included additional actors within the system. We also had to incorporate an additional element in our framework as it became clear that we had to elaborate on what type of innovation we were observing. Hence, the boundaries for the thesis were adjusted as the study proceeded, which is in line with the systematic combining approach by Dubois & Gadde (2002, 2014).

Through the use of the approach described above, our understanding of TranSys evolved. It involved both the questioning of previous rationales, as well as taking a step back to discuss findings in order to full grasp their implications.

As few previous studies have examined accounting calculations' role in the context of socio-technical change, we had no clear initial foundation to build upon. Our literature review (see 2.1) showed that while the accounting literature has elaborated on innovation development within single organizations, little had been said about the innovation development within systems. Through the investigation of adjacent literature, we identified other research fields attempting to analyze the phenomenon and drew upon that knowledge to develop a theoretical framework that would enable an analysis of the empirical data.

3.2 Data Collection

3.2.1 Primary Data

Primary data has been collected through semi-structured interviews with a broad mix of actors within the system. Over a period of four months, 18 interviews have been conducted with representatives from 10 separate organizations, each lasting between 30-90 minutes. The interviews were semi-structured since it reduces the risk of divergent interview styles (Bryman and Bell, 2013), given that we were two people conducting all interviews except one. Further, Maxwell (2012) stated that semi-structured interviews help to ensure the comparability of data and usefulness when discussing differences between people and settings, while the free element allows for exploration of unexpected phenomenon. Each author had a specific role during the interviews as either lead interviewer or secondary interviewer and note-taker. This approach was selected in order to facilitate an improved flow during the interview, but also in order to gain different perspectives of the interviews, increasing the objectiveness when later analyzing the data (Eisenhardt, 1989).

The interview candidates included in this thesis were selected using two main methods: recommendations from our thesis tutor and the Project Manager, and recommendations from the interview subjects who at the end of each interview was consulted on additional people of interest within TranSys. All suggested candidates, especially those suggested from other interviewees, were first discussed between the authors before deciding whether or not to try and include them in the thesis. Moreover, continuous discussions were held with the thesis tutor and Project Manager to decide which leads to pursue. Pertaining to those discussions, it further highlights the difficulties with the system format, as there was large uncertainty regarding which candidates that would be interested in, as well as rewarding for, our particular research question. Finally, all interviewees were anonymized as far as possible in terms of names and hierarchical level. Two quotations that were perceived controversial by either the interviewees themselves or the authors have been entirely anonymized.

As the case system included organizations from the public sector, the whole system could be deemed as a political environment. One organization was also a daughter-company to another, but due to their different roles and perspectives in the system, they were seen as separate entities. No single actor had full ownership of the case system, resulting in interviewees being reluctant to

comment too specifically on factors concerning other actors within the system. However, with the support and help from the Project Manager, the interviewees selected for the thesis were, in general, both enthusiastic and open to more in-depth discussions.

3.2.2 Secondary Data

The study also made use of secondary data such as internal documents and documents produced for the system as a whole. Those documents mainly consisted of presentation material and reports. By complementing qualitative data with quantitative data, we were able to strengthen the findings of the qualitative part (interviews) and mitigate the risk of findings being based on false impressions (Eisenhardt, 1989). The notion of being able to double-check our findings is also stressed by Dubois & Gadde (2002).

3.3 Data Analysis

All interviews were recorded, listened through and transcribed directly after they were finished. The transcriptions aided the process in several ways. First, it enabled us to discuss and confirm the findings from each interview. Second, it helped us identify areas of improvement in how we conducted our interviews, whether it was general layout of the session or the further inclusion of specific questions. Third, it helped us to find nuances in the answers we received, which facilitated our analysis later on. This served as an important process to increase our knowledge about the case, which is in line with Eisenhardt (1989). Themes and elements that corresponded with the theoretical framework were constructed, which enabled us to classify, sort and arrange data to highlight trends and links to test our theories and serve as a basis for our analysis. Overall categories, such as each level of socio-technical change, were broken down into subcategories such as type of innovation, type of calculative instrument and so forth. The main reason for this approach for the data analysis was, apart for enhancing our research process, to prevent information-processing bias as the interviews were processed in a number of different ways and in a structured manner, which Eisenhardt (1989) recommends.

3.4 Research Quality

3.4.1 Validity

Validity concerns how well the outcome reflects the studied reality (Yin, 2014) (Merriam, 1988). Yin (2014) separates the concept into two parts, internal validity and external validity. Internal

validity concerns the risk of authors interpreting the data in a subjective manner (Merriam, 1988). Internal validity is achieved through careful analysis of the data (Yin, 2014), and in this case it was achieved by using explanation building (the ongoing process of comparing empirical findings with theoretical predictions), and pattern matching (the matching of the predicted events with the actual findings). Both these methods are practices that improve internal validity (Yin, 2014). External validity concerns how well the results from the study may be generalized (Merriam, 1988). As this study is designed as a single- case study the generalizability of the results will be low (Yin, 2014). However, this is not a major concern as the deliverance of generalizable results is not the main purpose of this thesis (Merriam, 1988).

3.4.2 Reliability

Similar to the concept of validity, reliability may also be helpfully dichotomized between internal and external reliability. Yin (2014) defines external reliability as the extent to which the study may be repeated by other researchers, hence singling out how much of the study that has been affected by temporary and random conditions (cf. Bryman & Bell, 2013). Pertaining to the method theory developed in section 2.2, this study was to a large extent affected by the ongoing socio-technical change occurring within TranSys. As our findings were obtained during a specific moment in time, other researchers would probably struggle to identify a case system with similar characteristics. With that said, if such a system would be identified, the method theory used in this thesis is based on comprehensive research within the field of socio-technical change, indicating that other researchers then could be able to obtain similar results.

Internal reliability refers to the authors or members of a research team and to what extent they agree upon how to interpret what they observe (Bryman & Bell, 2013). The authors of this thesis have been involved in all steps of the process, from development of the theoretical framework to data collection and analysis, which should decrease the risk of subjectivity and hence increase the internal reliability. Moreover, the level of agreement between the authors have fluctuated during the process, often increasing first after repeatedly discussing findings and potential perspectives for analysis, which is believed to have strengthened the end result and facilitated a deeper analysis of the collected empirics.

4. Empirics

This chapter presents the findings from the case study. Based on the developed theoretical framework in section 2.3, we have structured the empirical review in three different sections: Socio-technical Landscape, Socio-technical Regime and Technological Niche. Section 4.1 provides the reader with an introduction to the background behind the socio-technical system. Section 4.2 outlines the dynamics within the socio-technical landscape, including the current landscape pressure taking place, how different actors within the system responds to this and how this is translated into accounting calculations. Section 4.3 describes the socio-technical regime and how it currently operates. Finally, Section 4.4 describes the technological niche level, which provides a more detailed description of the ERS project.

4.1 Background and Context

4.1.1 Swedish Political Directives

In a new climate law, which was put into effect January 1st 2018, the Swedish Government set nationwide goals on how the climate effect must be reduced in the future. In year 2030, the total CO_2 emissions from domestic transportation (excluding air travel) in Sweden should be reduced by 70 percent (compared to the level in year 2010). Further, in the year 2045, the Swedish government has stated that Sweden should have zero net emissions of greenhouse gases.

The Swedish government agency *Trafikverket* is responsible for "*the long-term planning of infrastructure for road transportation, railroad transportation, transportation by sea and transportation by air, as well as the construction and maintenance of public-owned roads and railways"* (Trafikverket, 2018). In their prognosis for the year 2030 and 2050, they see a minor decrease in total greenhouse gas emissions. Their conclusion from this is that technical initiatives such as more energy efficient vehicles and fuels will not be enough to achieve the goals set by the Government. Instead, they argue that it will require a new focus in the planning and development of society and its infrastructure. Back in 2008, Trafikverket did not know how this new infrastructure should be designed, but the transportation industry claimed that they knew the design for the infrastructure of heavy-freight transportation. Therefore, the transportation industry was challenged by Trafikverket to present a demonstration of how heavy-freight transportation would become less fossil fuel reliant and offered to co-finance the endeavor. A number of projects and

ideas were presented from different consortiums of actors, and one of the projects chosen was the ERS project.

4.1.2 Electrified Road Systems (ERS)

Electrified Road Systems (ERS) is a family name for all technologies using electricity in road transportation, For the basis of this thesis, the innovation project within TranSys will be referred to as *the ERS project* going forward. According to the Intergovernmental Panel on Climate Change's Fifth Assessment Report, the global transport sector is responsible for 23 percent of total energy-related CO_2 emissions, 72 percent of which are attributable to road transportation. ERS is increasingly highlighted as a potential future revolution of road transportation that would substantially decrease its combined climate effects. The ERS project makes use of old knowledge in a new context. It uses the same technology used in trams but modify the components so that they can be fitted in a road transportation environment. This means that an electrified overhead wire has to be built along the road and a pantograph device has to be fitted on a vehicle that is capable to run on electricity.

4.2 Socio-technical Regime

The socio-technical regime accounts for the stability in an existing socio-technical system (Geels & Kemp, 2007), which for the sake of this study is the Swedish land transportation sector. The regime consists of the main stakeholders, the formal, normative and cognitive rules and resources that makes up the current system.

Stakeholders

The consortium behind the ERS project consisted of a number of different organizations, some who were already actors in the incumbent system and some who would be actors in the potential new system. The old system is made up of **TransCo**, a transportation company, **SteelCo**, a buyer of transportation services and **HarborCo**, a harbor that serves as the end or start of many heavy-freight transportations in the area. **TruckCo**, a truck manufacturer supplies trucks for TransCo, while **RoadCo**, the governmental agency responsible for the Swedish road and railroad networks, conduct maintenance for the transportation routes. The transportation routes for the ERS project are situated within the municipality of **PublCo,** who also owns HarborCo. The main stakeholders impose their will on the system through formal, normative and cognitive rules that creates the

practices and general norms for the existing system. Figure 2 describes the incumbent system of TranSys.

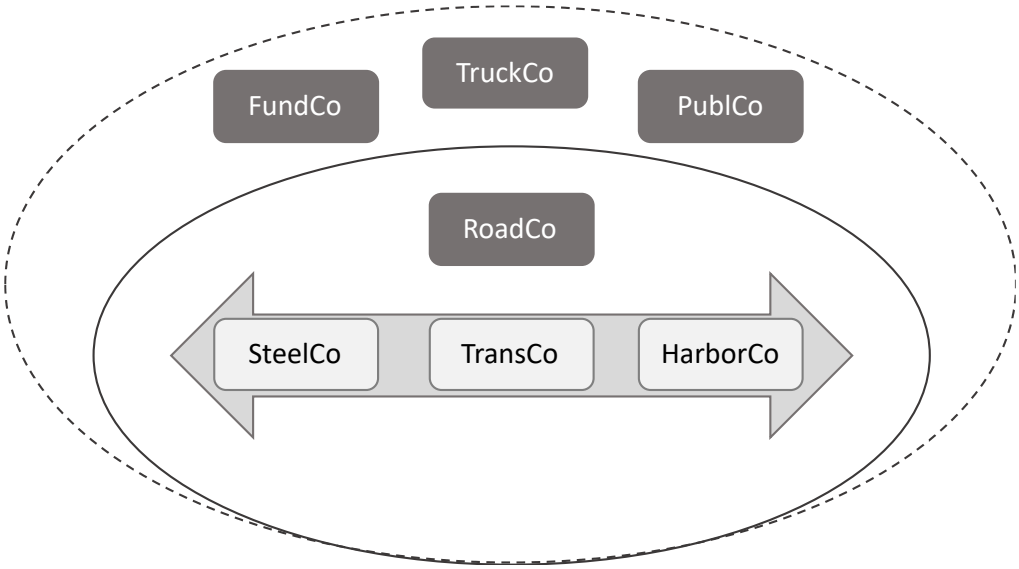

Figure 2: The actors within the incumbent system of TranSys.

Rules and practices

For SteelCo, the general norms and practices for the existing system express themselves through a standardized procurement process, as described by the Procurement Manager: *"We use software that is great for procurement of transportation. We upload historical transports, number of destinations, number of trucks, occupancy level, distance fully loaded versus distance unloaded, and then we take that into relation with weight tariffs"*. Transportation costs constitute approximately 10% of SteelCo's total costs. The costs for personnel, raw materials and energy make up the majority of the remaining cost base. As a company, SteelCo always consider costs through cost-cutting initiatives, and they identify transportation costs as one of the items with the potential to reduce costs. As of today, they mainly attempt to realize that potential through optimizing actions, such as maximal occupancy levels. However, there are also initiatives attempting to challenge the industry as a whole, as stated by the Procurement Manager: *"We work in what we call horizontal collaborations, which means constantly challenging the current transportation structures. Searching for new suppliers as well as aiding suppliers finding additional cargo to reduce the total costs and in extension our costs".* While the procurement process is well established, it still demands a lot of work and usually takes around 7-8 month to complete. In addition to price, the factors included in the procurement process are; sustainability efforts, guaranteed capacity, safety efforts, relations with sub-suppliers and means of

transportation, where the last factor are deemed most important through a sustainability perspective, according to the Manager at SteelCo: "*Our contribution to environmental friendly transportation at the moment is mainly that we try to transport as much as possible on trains (...). Our sustainability goals are expressed in railroad terms. We have to have a specific percentage transported on rails".*

Railroads as a mean of transportation for goods is currently subject to debate. While some argue that railroads will play a minor but still serviceable role in goods transportation in the future, others believe it will become entirely obsolete due to high prices, inflexibility and the emergence of other environmentally friendly options. Although the actors disagree to what degree the use of railroads will decline, the notion that *it will* is agreed upon. Moreover, most of our interviewees also agreed upon how the view of declining usefulness of railroads is not shared by the government, who continuously champion its use. Hence, alternative infrastructure investments have a harder time attracting funding. The trucking industry was also suggested to be viewed in a less flattering light by certain levels of government, as described by one of the interviewees: "*Some see trucks as evil and there seems to be nothing that can change that view."*

The regime also consists of a financial network with the aim to identify certain infrastructure investments. **FundCo** has conducted several infrastructure investments in the region before and may act as both an investor and an advisor. FundCo is an international actor who work on the directive of the European Commission. They borrow capital on the capital market and subsequently lend money to investment opportunities throughout Europe. Typical investments are large infrastructure projects such as railroad systems and hospitals. FundCo operate under the directive of not making profit and only lend money over longer time horizons. However, they analyse potential investments by the criteria of being both beneficial for society and a sound financial investment, according to the Manager at FundCo: "*It has to be a sound and sustainable investment. This is not simply to get our money back. A lot of effort goes into the risk/reward analysis"*. When analysing prospective investments, one of the measures employed is Incremental Rate of Return (IRR), but it is far from the only factor: "*It is very different depending on the projekt. We conduct an analysis based on the benefit and impact on society. The analysis is based on a model we've developed ourselves."* (Manager, FundCo).

For TransCo, who are responsible for facilitating transportation of goods within the system, the calculation for transportation is similar in most cases. First, they consider the capital cost of purchasing the truck, which may vary depending on the type of truck. The initial capital cost for a truck varies between 1.5-3.5 MSEK in today's regime. When pursuing the investment, TransCo considers the payoff time depending on the type of truck. If it is a shift-truck, meaning it will be driven in shifts, the payoff time is usually 3-4 years. In contrast, if the truck is meant to be used on a daily basis the payoff time is set at six years. Second, they consider the costs of maintenance and repair of tires, powertrain and engine by looking at years of historical data. Third, all tenders have a price effect concerning capacity level. If TransCo can't secure capacity both ways of a transport, it will effect the quoted price. TransCo also always submit a section concerning the environmental impact of the suggested transport; *"We usually explain how the specific transport will be performed using a specific fuel, resulting in a number on CO_2 reduction"* (Manager, TransCo) but their focus on the environment is not entirely uncontroversial. The sector has well established norms and behaviors which also serves as barriers to change: "*The trucking industry has a strong tradition of horsepower, design varnish and so on. For many truck drivers this is a way of life which one have to respect"* (Manager, TransCo).

A lot of TransCo´s transportations go through the harbor. HarborCo owns the land and buildings while parts of the operations are leased to various private companies. HarborCo earn their revenue from the leasing, but also through fees from ships docking there. HarborCo is owned by PublCo and has to balance the need of having an efficient and profitable business while satisfying the enhanced responsibilities that comes from being owned by the municipality PublCo, such as environmental improvements. One example of how this manifest itself is that HarborCo collect reduced fees from ships that fulfill higher environmental standards. There have been discussions if similar fee structures should be imposed on land-based transports, which are exempted from fees today. The trucks used by TransCo to transport to, and from, HarborCo are produced by TruckCo.

Resources

TruckCo is a global truck manufacturer operating through the use of a *modular system*, which is a system utilizing as few unique individual components as possible. Base modules serve as skeletons

on which interchangeable parts are mounted. The modular system enables lower cost structures and adaptable production processes. TruckCo currently focus on several technologies such as traditional diesel trucks, electric trucks, hybrid trucks and biogas trucks. *"Our modular system enables us to adapt the trucks to different power sources relatively efficiently. We will not have invested us into a corner"* as the Manager at TruckCo explains it.

While the political establishment is actively working towards an industry shift away from fossil fuels, the government does have an ongoing monetary interest in the use of diesel and petrol, as they provide substantial sources of income to the state. As stated by Business Developer B at RoadCo: "*Fossil fuels provide 70 billion SEK in tax revenue each year. How is this going to be replaced?".* If a substituting source of power becomes dominant enough to replace fossil fuel, many are worried about how the tax burden will be transferred to the new business model. This results in pressure on all potential replacing technologies as the taxes make up around 50% of the prices of diesel and petrol today. How will a new power source with an even higher efficiency rate, such as an electric engine, be taxed if it is introduced in a larger scale? This is pointed out as a large hindrance for change by many of our interviewees.

Today, railroads are subsidized and perceived as the best option from an environmental perspective, but according to several actors, train transportation is not a viable solution to drastically lower carbon emission. The Swedish railroad network is currently heavily burdened and in need of maintenance. Although large investments to address these issues might be on the horizon, these are not expected to enhance the capacity enough. Instead, our interviewees expressed concern that the investments would temporarily lower the capacity as they would transform large parts of the railroad network to construction sites for several years. This would take place simultaneously to actors experiencing even more pressure to adapt their operations to become more environmentally friendly.

4.3 Socio-technical Landscape

The socio-technical landscape level symbolizes the setting and events outside regime actors control (Geels, 2005). It is the forces that the actors themselves cannot influence but have to react

to, and hence slowly change the niche and regime. In the context of this essay the landscape is the initiatives, policies and attitudes derived from concerns about climate change.

Pressure from climate goals and policies

Concerns regarding climate change and our impact on the environment are becoming increasingly important for organizations. In the system of TranSys, RoadCo have an important role for these concerns as they are tasked to plan and maintain the road and railway networks. Although not solely responsible for the advances of the transportation industry in terms of reductions in carbon emissions, RoadCo strives to enable a shift towards a transportation sector that fulfills the requirements in their political directives. This has an impact on RoadCo's decisions regarding maintenance and investments. The signals sent by policy makers can also have implications for supply and demand: as pointed out by the Manager at TruckCo through a seperate example: "*Two years ago, in Paris, they started to talk about forbidding diesel powered vehicles in the city and this mere discussion caused the second-hand value of diesel trucks in France to fall. This was even before it was clear whether that kind of restrictions would be compatible with French law."*

As previously mentioned, the government is putting pressure for a shift in the transportation industry through the use of taxes. High taxes on fossil fuels act as an incentive for actors to shift to alternative fuels, but this is not uncontroversial. While some argue that steeper increases in taxes would accelerate the transition, others argue that it would have weakening effects on the industry: "*We do not see that the politicians are thinking along the right lines regarding this. The state tries to force transport buyers to switch the type of transportation used by using different taxes, but this will only serve to weaken the competitiveness of Swedish industry. We are not situated at the centre of global commerce, we need efficient transportation to reach our markets"* (Procurement Manager, SteelCo). Parts of the pressure to improve SteelCo's climate efforts emanates internally. All companies with a turnover above 500 MSEK are required to produce a sustainability report. Therefore, companies are forced to set clear and ambitious goals and policies regarding the environment, which was also pointed out by Procurement Manager at SteelCo: "*I of course want transports that are free from carbon emission, that are as friendly to the environment as possible. It might be something that I am willing to pay a little more for but how this is done is up to our forwarding agent. Our main concern is how much CO_2 that is emitted when transporting our goods over time*". This translates into a rising demand for environmentally friendly transportation within

the industry, which has led transportation providers to shift focus as their customers demand life-cycle analyses of their services: "*We are the country's leading green haulage contractor. We have not used fossil fuels since 2015. This green profile has helped us win market shares"* (Manager, TransCo). Additional to the pressure from policies are the pressures emanating from attitudes.

Pressure from attitudes

The widespread environmental concern is forcing companies to transform the way they operate, and while it sometimes results in increasing costs as new parts or methods have to be introduced, it also offers some possibilities. Companies that are in the forefront of their industry's environmental development are often more positively perceived by customers, as environmental concerns are increasingly becoming a factor during purchases. Hence, this may lead to companies developing a competitive edge, as pointed out by both the Manager at TransCo; "*Part of the competitiveness of Swedish steel will be that it is sustainable",* and the Manager at HarborCo; "*For us, reduced CO_2 emission initiatives present a possibility to increase revenue in the future as some transports in our region are currently steered towards other ports. If we would offer a solution that no one else can, I see a real possibility that the actors will start steering their transportation routes through us instead* ". Environmental impact is also a frequently discussed topic in media and environmentally friendly firms receives more publicity, as experienced by the Manager at TransCo: "*Our company and the other actors involved in this has gotten a lot of free and positive publicity because of this. The truck has been paraded around the country with photo opts at companies' annual meetings. Many have asked what I had to pay for all this"* (the truck is painted with the company's logo).

Even firms that are not directly involved in the innovation project has benefited from it, as the mere association with the involved companies has been highlighted in marketing campaigns. While many testify that working actively with environmental issues can boost a company's sales by making the company more attractive in the eye of the customers, the enhanced reputation is also necessary to make the firm an attractive place for employment. "*We have a generational shift. Our new drivers are born in the 90's and have grown up with the concerns of climate change. For them this is very important, and we stand out as we are light years ahead of most of our competition regarding the environment"* (Manager, TransCo). There is a notion among the interviewees that

this aspect will only become more important in the future when younger generations, who are perceived to be more concerned with the employer´s environmental policies compared to older generations, will constitute a larger share of the workforce.

4.4 Technological Niche

The Technological Niche level is the bubble of innovation in which new technologies are developed. It is secluded for the real world and serves as a learning environment for novel technology, behavior and structures but can with the help of landscape pressure break through the bubble and affect, or become part of, the socio-technical regime.

The new actors and roles

The new roles in TranSys would be a supplier of the technological infrastructure, with the global industrial conglomerate **TechCo** as a possible candidate, and an electricity provider, with the energy company **ElCo** having expressed their interest. Additional infrastructure would also have to be built, and ElCo, TechCo and RoadCo are all possible candidates for that construction, using either external or internal funds. FundCo would be a possible source of external funding. Figure 3 describes the actors in the potential new system of TranSys.

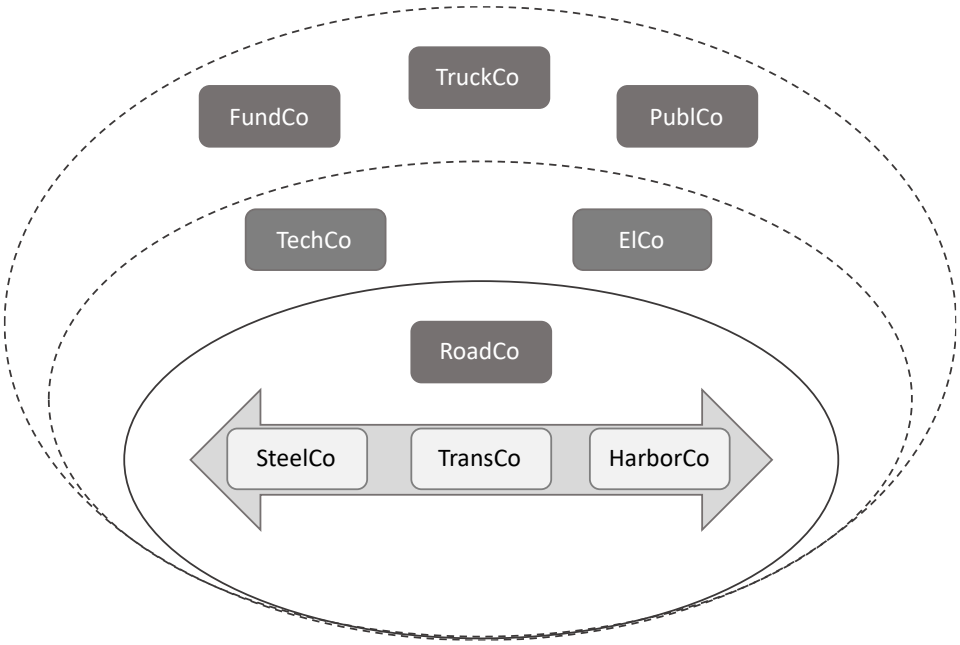

Figure 3: The potential new system of TranSys.

The idea for the innovation project originated at TechCo, who saw the potential for a new revenue stream. TechCo already produce technological infrastructure systems for trains and wanted to leverage that experience in the development of a more environmentally friendly sector for transportation by trucks. In the context of the ERS project, TechCo are interested in supplying, operating and/or providing maintenance to the technology and are actively advocating for its commercialization to other actors within the system. TechCo use a *system breakeven-analysis* as part of their arguments, which is a calculation on the profitability for each actor in a hypothetical new business scenario. While several aspects of the operations would be similar for TranSys if the new technology was implemented, it would be dependent on three new components; an overhead cable infrastructure, a modified truck capable of utilizing direct current and a pantograph device to connect the overhead cable with the truck. Although the specific business model for this new scenario is still under discussion, several interviewees state that it will correspond to three major adjustments in the transportation calculation. It will require a fee as payment to the owner or operator of the infrastructure, a higher initial capital investment for the modified truck and the substitution from diesel to electricity as fuel. The gain to be achieved from switching fuel source has been calculated to a reduction of 66 percent in fuel costs, which has to be balanced against the higher capital investment for the truck and fee for using the electrified road. As mentioned, ElCo would be interested in supplying the electricity, but the Manager at ElCo also expressed their interest in owning and/or operating the new innovation system: "*We build, serve and administer power grids all over Sweden. This should not be that much of a difference. We could be responsible for the infrastructure in its entirety"*.

The notion of the ERS project being based on old technology, and that it wouldn't drastically change current business models, is a view that is expressed by several of the interviewees. Although currently only involving a few actors within each respective sub-industry, there is a belief that other actors would utilize the innovation and generate momentum through market forces if the innovation would be launched. A prerequisite for such a development is that the currently idle companies would be able to deploy products that could be functional and competitive in the transitioned system. Due to characteristics of the innovation and the ERS project, the Project Manager stated that; "*This technology is 70 years old. It is basically trams",* and the Manager at PublCo shared similar views; "*this project involved no patents on any of the significant*

components". This has served as a reassurance for many of the involved parties, who otherwise would have been concerned with one or a few actors acquiring too much influence over the system. TruckCo already supplies the project with a prototype hybrid engine that is marginally modified and argues that they already have the technological knowhow to produce the required truck commercially within a year or two.

Although the ERS project was initiated as an environmental project, there is a widespread pragmatism regarding the potential financial gain for TranSys as a whole, which is described as the real engine for the development. "*This is all about increased efficiency, not the environment. When all is said and done, this is what really powers the project*." (Business Developer B, RoadCo). The project would also result in a change in the roles of RoadCo and PublCo, compared to their current roles within the socio-technical regime. The Manager at PublCo describes how they are acting on behalf of the public interest to reduce the greenhouse gas emissions and use their role to try and enable the change: "*We are business tailors. We do not have any direct economic gain in this we instead try to use the official capacity of the municipality to drive change. We talk to people and try to get a picture of how their reality look today and what their needs are"*. They stress a societal perspective for the ERS project and argue for its effect on the surrounding economy as a whole: "*We look at things such as air quality, noise levels, these kind of things (...) We look at this from a planned economy perspective"* (Manager, PublCo). For example, reduced noise levels in cities would make them more attractive for new residents. Another benefit could be reduced air pollution from the surrounding trafic, which would lead to healthier citizens. PublCo are working on how to adapt local businesses towards the potential ERS project, as it has the potential to create several adjacent business opportunities such as specific maintenance requirements.

For TransCo, the ERS project would have an impact on their usual maintenance and repair routines, as the new technology would result in wear and tear on components (tires, powertrain and engine). TransCo would also have to buy a pantograph device to connect the ERS adapted truck to the overhead lines. The cost of these products remains unclear: *"The main uncertainty in the calculation is the new capital investments. It will depend on how many items the producer expects to sell"* (Manager, TransCo). In terms of electricity, TransCo feel comfortable with the

calculations they have been able to conduct to date. The fuel costs of electricity will probably correspond to ⅓ of the current cost for fuel. It is when you consider the different aspects of the two types of engines that the calculation proves useful: *"The real money lies in the fact that electricity costs 0.35-0.40 SEK per kWh, which is utilized by an electric engine with a utilization factor of above 90%. Put that in contrast to a diesel price of 11 SEK per liter in an engine with a utilization factor of 35-40%. This calculation is the basis for motivating a higher capital investment and a subscription fee for the road itself"* (Manager, TransCo). TransCo have also considered the payoff time in terms of second-hand value. However, the different dynamics of a hybrid truck, which would mostly be driven using electricity on the developed road, leads to potential new ways of addressing that factor according to the Manager: "*Let's say I buy a hybrid truck for 2.5 MSEK, which will be mostly be driven on the electric road. After the payoff time of 6 years, the combustion engine in that truck will be relatively new. Then I can remove the pantograph and allocate that truck to another assignment, or even sell it second-hand internationally with a basically new powertrain and engine. This is a new business opportunity that would be created through this project".*

A similar observation was made by SteelCo, who's initial interest in the project derived from the possibility to reduce the company's environmental impact. They identified an additional sales opportunity as the new infrastructure of the ERS would demand a lot of steel. For HarborCo, the potential ERS would present an opportunity to increase volumes without an increased environmental impact. Whether or not this also could result in additional revenue streams remains unclear. HarborCo could introduce a fee structure that rewards environmentally friendly transports similar to their current handling of incoming ships. However, as no fees are currently being collected from trucks, the introduction of new fees are viewed as more problematic than providing a discount. Further, it would be problematic as the efficiency of the potential ERS would depend on frequent traffic, which implies that a road with little traffic would not be chosen for the ERS implementation.

For TruckCo, the ERS project is not expected to meaningfully change their way of doing business. As previously mentioned, the current prototypes that are up and running on the ERS and the company believe they have the technological knowhow to make a commercial product in the near

future. They believe that there will be market for the ERS but are having difficulty forecasting when it will materialize as it depends on many other actors: *"Our challenge is and were how to prioritize this against our other R&D projects"* (Former Manager, TruckCo).

Obstacles for the continued transition

The introduction of ERS would have various impact on the individual actors' operations within TranSys. While some would be required to make investments that are viewed as substantial in size, the time horizon for the investments was viewed as more important among the interviewees. It was agreed that the ERS innovation was an efficient solution for reduction of environmental impact, as well as viewed by the majority as the only viable solution that would enable the industry to reach the 2030 climate goals. However, several interviewees expressed the concern of future technologies having the potential to be even better. For example, one interviewee stated that: "*My main concern is what happens with the development in the battery industry. Could they provide a viable solution for heavy duty transport within the foreseeable future? Will we be able to charge vehicles through induction? Batteries in full flight? If we could, this technology would be wrong. I would not want to the minister for infrastructure and invest billions in the infrastructure just to see the technology overtaken".* The depreciation characteristics of actor's potential investments was therefore highly indicative for the actor's risk appetite. For the owner of the new infrastructure, the long-term usefulness of the ERS is adamant as the investment would require a long payback time. The payback time would also differ depending on the magnitude of the implemented ERS. Both ElCo and TechCo have the resources and will to invest in the infrastructure, but none of the actors are prepared to solely acquire all the risk associated with the investment. *"We are prepared to build, own and operate this but we would need some guarantee to at least get our money back"* (Manager, ElCo) or as expressed by the Manager at TechCo: *"If they (RoadCo) do not say under what premise this would work we cannot not take the risk. They* (RoadCo) *could say that after 7 years you are going to be bought out for X millions, that would work in our books.*

The buyer (TransCo) and manufacturer (TruckCo) of the new trucks face less risk exposure and uncertainty as the depreciation time would be much shorter compared to infrastructure investments. According to the Manager at TruckCo, they wouldn't be opposed to investigate potential methods of reducing the risk for their customers: "*Tesla initially guaranteed the second-*

hand value of its vehicles to infuse to infuse some security in its buyers. We could do something similar". For TransCo, the typical usage time of the purchased trucks is between 3-6 years. However, the remaining uncertainties of the exact investment requirements and their magnitude still hinder the further development of the ERS, as described by the Manager at FundCo: *"We have a Catch 22. The truck supplier has to know that they can sell the trucks in order to initiate production, and the truck buyer has to know the price of the new truck in order to start purchasing it".*

5. Analysis

This section analyses the findings presented in chapter 4 in relation to our domain theory described in section 2.1. Section 5.1 analyses the empirics through the Multi-level Perspective framework, highlighting similarities and discrepancies with previous research. Section 5.2 concludes our analysis by discussing our findings in relation to the formulated research question.

We have sought to understand what we believe is an underdeveloped area in research on accounting's role in innovation, since recent research has focused mainly on individual organizations (e.g. Mouritsen et al., 2009; Revellino & Mouritsen, 2015). A few articles have touched upon the concept of socio-technical systems and change, with the call for further research through that perspective (Christner & Strömsten, 2015). However, there is a lack of exemplified methods within accounting research to tackle such a research angle, with the struggle of identifying an approach fit to capture the complexity of a large socio-technical system. In order to draw new conclusions and build on the emerging research stream of accounting's role in innovation, we have investigated the use of accounting calculations in the socio-technical system TranSys through the Multi-level perspective framework.

5.1 The Role of Accounting Calculations through the Levels of MLP

The role of accounting calculations within the socio-technical regime

The socio-technical regime is destabilized during socio-technical change (see section 2.2) and the window of opportunity is temporarily open for new innovations. According to theory, the socio-technical regime would work against the innovation and instead attempt to keep the status quo (Geels, 2005). However, in our case, there are additional aspects to address as several of the regime actors are involved in the development of the new innovation in the niche level. Our interviews show how some actors are using accounting calculations in a way that may constrain the innovation development (Abernethy & Brownell, 1997). Both SteelCo and TruckCo refer to existing calculation practices when discussing uncertainties of the innovation. SteelCo rationalize the innovation with the ambition to use the same procurement model, and hence largely the same calculations, even after the new technology would be implemented. TruckCo also mentions the second-hand value of the trucks, an important element of their current way of looking at costs, as a large uncertainty for them. FundCo express the need for a new capital investment due to the

innovation development to bear similar payoff-times as their current capital investments. We argue that the calculations above, in a way, act as a reinforcement of the current established practices, and therefore constrain innovation.

The suggested constraining role of certain accounting calculations within the socio-technical regime may be further explained through the concept of innovation characteristics. The accounting calculations used premiered the current methods of conducting business within the socio-technical system, which suggests that an incremental innovation, drawing on current knowledge (Gatignon et al., 2002), would have higher probability of being implemented within the socio-technical system. A more radical form of innovation, which would be a clear departure from current practices (Anderson & Tushman, 1990), would instead face resistance from the socio-technical regime. ElCo states how they are interested in investing in the new innovation but prefer a design that would favor their current ways of calculating business investments. While ElCo enabled a certain development trajectory for the ERS system by reaffirming the notion of them as operators, their expressed preference for their current calculative practices simultaneously reduced the probability for alternate forms of calculations for the business case. This is in line with the findings of Christner & Strömsten (2015), who found that the enabling or constraining effects of accounting calculations are non-binary. They saw that the enabling of certain development trajectories resulted in the constraining of others (Christner & Strömsten, 2015).

Mouritsen et al. (2009) showed how accounting calculations serve in a competitive space, which was later developed by identifying that the competitive nature may lead to counter-performativity (Callon, 2010). The political plane of TranSys exhibited similar traits in our study. Initially driven by the calculation showing how the innovation project may enable efficiency gains throughout the socio-technical system, parts of the political establishment later acknowledged how the reduction in use of diesel due to the innovation would result in vast amounts lost in tax income. Although temporarily hindering the development of the innovation, it also reaffirms the notion of accounting calculations helping to transform the effects of innovation from more technical to economic (Davila & Wouters, 2004). Moreover, the calculation concerning tax effects also contributed to the ongoing discussions on how to design a business model for the potential launch of the

innovation. Hence, it triggered an additional process of mobilization of insights that will become part of the implementation of the innovation (Revellino & Mouritsen, 2015).

The role of accounting calculations within the socio-technical landscape

As described by Geels (2005), the socio-technical landscape of a socio-technical system is forces beyond the control of actors that they instead have to react to. The main guiding force for TranSys is that of climate impact, as the transportation sector is responsible for substantial amounts of greenhouse gas emissions. Hence, the management accounting calculations used to affect the innovation processes within the socio-technical system are closely connected to factors of climate impact.

At TranSys, the landscape pressure is translated through various management accounting calculations to establish context with each actor. SteelCo's main concern was the figure for CO_2 emissions connected to their transported goods. TransCo found a competitive niche by deploying a green profile. However, our interviewees agreed that their initial calculations of the landscape pressure highlighted that the possible measures currently at hand would not be sufficient. This is in line with the study by Mouritsen et al. (2009), who explored the concept of long and short translations. Short translations are defined as when management accounting calculations encourage extension or reduction of innovation activities by either highlighting performance as adequate or inadequate (Mouritsen et al., 2009). In the case of TranSys, the quantification of environmental impact that was attained through the climate goals extended the innovation activities towards other sources of energy than fossil fuels. The accounting calculations stemming from the environmental pressure also helped create visibility within the established socio-technical system (Robson, 1992). While many of the actors have individual climate goals advocating for more use of the railroad network, The calculations also highlighted the insufficient resources in the current regime, as the railroad network was in such poor shape that focusing on it could not be deemed as financially sound and hence helped form a direction which concurs with Miller & O'Leary´s (2007) observations.

The role of accounting calculations in the technological niche

The technological niche level serves as a "bubble" where innovations are free to develop without the pressures of the free market (see section 2.2). As mentioned before, several of the current actors within the socio-technical regime are contributing to the technological niche level in the ERS project. During our interviews, many of the actors being part of both levels expressed how the innovation development aided them in identifying additional business opportunities. SteelCo started calculating what components that would be included in the new innovation and identified themselves as potential steel producers for the steel bars connected to the road. RoadCo turned the concern of second-hand value of the new trucks to an opportunity to modify the truck to regular hybrids and resell them to the global market. HarborCo saw that an ERS connected to their facilities would enable them to solve the business conundrum of increasing business volumes without increasing the environmental impact. This additional value, beyond the initial scope of the innovation, is line with Revellino & Mouritsen (2017) who found that the innovation of automated toll collection in Italy resulted in additional value in the form of safety improvements and environmental preservation.

According to Robson (1992), accounting calculations have the capacity to create visibility. He argued for the concept of action at a distance, meaning how accounting calculations provides a link between "here" and "out there". We argue that the case of TranSys reaffirms this view and it is manifested in how the accounting calculation of depreciation is used between actors within the technological niche level. Through our interviews we found that, depreciation, at times had served as a fixed accounting calculation that enabled actors to analyze their own needs and exposure in terms of other actors. Further, we argue that this exhibits how accounting calculations may be used as mediating instruments within development processes (Miller & O'Leary, 2007). The accounting calculation of depreciation also triggered a mobilization of knowledge, as to what each actor would be able to accept in terms of investment characteristics, which would become part of the innovation if it is introduced full-scale (Revellino & Mouritsen, 2015).

The current developments within TranSys was initiated with the pressure of climate change and environmental impact. However, as focus increased on the particular ERS under development, there was a shift from viewing it as an environmental initiative to an efficiency initiative. The

technology that was part of the innovation proved to be substantially more efficient than the existing one, and our interviews showed how many actors were guided by the potential for cost savings and/or profitability increases. This is in line with the view of Davila and Wouters (2004), who showed how accounting calculations can transform the effects of innovation into more economic terms. Further, this reaffirms how accounting calculations concerning development in profitability can make markets more visible for actors (Hines, 1988; Quattrone & Hopper, 2005).

5.2 The Role of Accounting Calculations in Socio-technical Change

In our theoretical framework we identified how the MLP framework enabled a dichotomization between three distinct levels of a socio-technical system. The empirics and subsequent analysis above suggest that accounting calculations are used differently between the three levels, which has implications for the development of the innovation and in extension the socio-technical change.

First, the accounting calculations used in the socio-technical regime served as a reinforcement of current established practices, and thereby constraining innovation (Abernethy & Brownell, 1997). The advocating of currently used calculative practices also had implications for the type if innovation attempting to break through the W/O. We observed how the use of current accounting calculations shaped the development trajectory of the ERS towards more incremental characteristics. The view on accounting calculations expressed by ElCo further highlighted similarities with the findings of Christner & Strömsten (2015), who suggested that the enabling and constraining characteristics of accounting calculations are non-binary. Moreover, the use of accounting calculations within the socio-technical regime also highlighted their competitive nature (Mouritsen et al., 2009). Pre-existing calculations guided the development within the socio-technical regime and when they didn't fit with factors emerging from the innovation development, they imposed a constraining effect. Second, the accounting calculations facilitated the translation of landscape pressure within the socio-technical landscape. In accordance with Mouritsen et al. (2009), this *short translation* facilitated an extension of the innovation activities as the pressure to reduce the use of fossil fuels became more concrete. It also created visibility (Robson, 1992) and highlighted how the existing modes of transportation would be insufficient for future investments. Third, the use of accounting calculations in the technological niche aided actors to identify additional opportunities connected to the innovation (Revellino & Mouritsen, 2017), such as parts

for the innovation infrastructure or new methods for handling second-hand assets. Moreover, accounting calculations where used to create visibility and as mediating instruments, specifically when discussing the specific calculation of depreciation between actors.

Accounting calculations were deployed differently between the socio-technical levels

We argue that our thesis shed a new light on how accounting calculations shape the development trajectories of innovation in socio-technical change. Although many of our findings correspond to recent literature within the domain, the breakdown of the three levels of socio-technical systems showed how the calculations were deployed differently within each level. We argue that the notion of accounting calculations as either enabling or constraining can be extended by including on what socio-technical level the calculations are deployed. Further, we find indications that accounting calculations affect different types of innovation differently within the context of socio-technical systems. While innovation that fits within established methods of calculation was encouraged (incremental innovation), more challenging innovation suggesting new methods for calculation would not be as easily implemented. Therefore, our findings suggest that accounting calculations in socio-technical systems not only shape the development trajectory of innovations, but shape the development trajectory towards more incremental innovation characteristics.

6. Conclusion

6.1 Conclusion

This paper contributes to existing research in the literature on accounting's role in innovation by drawing on research on socio-technical change. We answer a call by Christner & Strömsten (2015) and view the use of accounting calculations in the context of socio-technical systems. The paper aimed to answer the following research question: *"How do accounting calculations shape innovation development trajectories in socio-technical change?"*

The case of TranSys reaffirms several of the recent findings within the domain of accounting's role in innovation. The innovation activities within TranSys was expanded due to the translation of environmental impact (*landscape pressure*) into calculations of emissions reductions (Mouritsen et al., 2009). Accounting calculations was shown to act in a competitive space, and this lead to partial counter-performativity within the system (Callon, 2010). The calculations were also used to transform the technological aspects of the ERS innovation to the economic domain (Davila & Wouters, 2004). We observed how the innovation development process created additional value beyond the initial scope of the process (Revellino & Mouritsen, 2017), as actors developed new business opportunities due to the innovation.

Our developed theoretical framework shed new light on the research domain. We argue that the breakdown in socio-technical levels showed how accounting calculations are used differently within a socio-technical system. Although sometimes enabling, in accordance with most recent research literature, the accounting calculations deployed also exhibited constraining effects in the socio-technical regime. Hence, our paper expands on the recent notion of accounting calculations shaping the development trajectory for innovation processes (Christner & Strömsten, 2015; Revellino & Mouritsen, 2015). We argue that accounting calculations in socio-technical systems shape the development trajectory of an innovation towards more incremental innovation characteristics.

6.2 Limitations and Suggestions for Future Research

This paper has examined the role of accounting calculations in innovation in the context of socio-technological systems. By using the Multi-level Perspective framework, similarities as well as

discrepancies to current research have been observed but the distinct approach also entails limitations for our paper as well as suggestions for future research.

The decision to use a single-case study approach was not entirely straight-forward. A socio-technological system consists of numerous separate organizations, which may suggest the use of a multiple-case study. However, as argued in section 3.1, the characteristics of socio-technical systems in general, and TranSys in particular, call for viewing it as a single organization and thereby a single case. The use of a single case study enabled us to gain the breadth necessary to understand and analyze the case of TranSys as it stands today. However, future research could also view the socio-technical system from the perspective of a multiple-case study, which could lead to a deeper analysis of the intricacies of the phenomenon. Moreover, the findings of a single-case study are harder to generalize across different industries or organizations.

Furthermore, this study has been limited to the time given by the thesis period, which means that our observations end before the innovation process of TranSys is completed. There are clear limitations of only observing part of the whole innovation development process. Future researchers would benefit from conducting a longitudinal study to capture a larger part of the full empirics. Another limitation is that some organizations within TranSys were represented by only one interviewee, which suggests the risk of a degree of subjectivity in our empirics. The context of this specific study might also have affected our empirical findings. All interviewees showed a real passion and interest for the project which could have influenced our observations and interpretations and an additional layer of nuance could have been gained by identifying more actors with a negative view of the ERS project.

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8. Appendix

Number	Position	Length
1	Project Manager	90 min & 30 min
2	Manager PublCo	60 min
3	Manager SteelCo	40 min
4	Manager TransCo	80 min & 30 min
5	Business Developer A RoadCo	50 min
6	Procurement Manager SteelCo	40 min
7	Former Manager TruckCo	45 min
8	Manager TruckCo	65 min
9	Manager HarborCo	35 min
10	Business Developer B RoadCo	45 min
11	Business Developer C RoadCo	40 min
12	TranSys Researcher	60 min
13	Manager FundCo	50min
14	Manager ElCo	40 min
15	Employee HarborCo	40 min
16	Manager TechCo	60 min