Collaborative Measures
Challenges in Airport Operations

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Extended Abstract

Performance Measurement (PM) has become increasingly significant in most organizations. Over the last 20 years, internal use of PM within organizations has become much more complex in terms measurement techniques and approaches as well as their deployment within different organizational structures. In contrast to the traditional use of PM as an intra-organizational system, the emergence of networked operations, where actors often deal with a challenge of managing through Collaborative Measures has extended organizational boundaries of Performance Management System (PMS) to new operational settings. Given the critical role of PM as one of the main mechanisms for managing performance, it is surprising that inter-organizational PM has not been explored in a more purposive way especially within complex multi-stakeholder settings such as airports.

Managing through collaborative performance measures is potentially complicated to implement and to sustain. This is mainly because different organizations operate with differing views, priorities and interests, and sometimes these views, priorities and interests are conflicting. Consequently, there is a significant lack of feedback and feedforward reporting mechanisms for goal setting and goal attainment within complex multi-stakeholder settings. Moreover, the lack of a central decision making authority ultimately translates to a collaborative PMS being insufficiently dynamic and unresponsive. This raises an important question for Performance Measurement & Management (PMM) literature. How do actors manage through collaborative performance measures? Hence, the purpose of this thesis is to investigate PM dimensions how they affect the management of collaborative measures in a quest to attain better operational performance for inter-organizational PM.

To reach this purpose, the thesis builds upon four studies investigating a collaborative PMS for capacity enhancements in airport operations. Due to their operational complexity and highly networked sub systems, airport operations provided a fitting empirical scene for studying PM that transcends organizational boundaries. The studies relied on a multimethod approach, including, longitudinal action research, multiple-case study, Systematic Literature Review (SLR), Classification and Regression Tree method (CART) and Artificial Neural Network (ANN) Method. The multimethod approach was selected as it provided unique advantage to compare and contrast different findings to form aggregate conclusions from different sub units of analysis in the airport operation process. Within the context of this thesis,
airports are viewed as System of System (SoS) and inter-organizational PM is operationalized with the following dimensions: Organizational Complexity, Continuous Improvement and Social system.

There are four important findings realized in this thesis. First, as reported in Paper 1, the main challenges that organizations face while implementing a collaborative PMS are identified as: lack of clear collaborative goals, change of culture, poor role setting, poor information management and lack of a system integrator. Second, as reported in Paper 2, the study identified several complexity factors such as non-linear interdependencies, existence of informal roles between actors and number of actors and network size. Third, as reported in Paper 3, it was found that inter-organizational performance is affected by intra-organizational Performance Measurement Complexity (PMC) which aggregates as interactive complexity at the system level. Furthermore, as reported in Papers 1 and 3, results show that, the social dimension is affected by lack of trust in the measurement system and knowledge that is uneven in team structures. Additionally, Papers 4 and 5, showed how the process of continuous improvement lack interpretive rights to set new measures and how exogenous factors become critical for a collaborative PMS rather than actor’s roles.

The challenge of feedback and feedforward mechanisms as a dual control for collaborative performance is then associated with four cybernetic functions: sensor, commander, actuator and process. The concept of Reflective Performance measurement system is introduced with general and specific conditions to facilitate collaborative decision-making within such platforms. This study departs from previous research in PMM literature such as, Extended Enterprises, virtual enterprises, collaborative supply chains by investigating the misalignment between inputs and outputs within complex multi-stakeholder settings. Moreover, the study lays a foundation to rethink how the future of inter-organizational PM should be discussed and designed.

**Keywords:** Performance Measurement, Airport Operations, Collaboration Decision Making.
Sammanfattning


För att uppnå detta syfte bygger uppsatsen på fyra studier som undersöker ett gemensamt ledningssystem för mätning och styrning av verksamheten, huvudsakligen avseende kapacitetsförbättringar. Med operativ komplexitet och starkt nätverksbaserade delsystem är flygplatsverksamhet en lämplig verksamhetsmiljö för att studera måt- och styrsystem som överstiger organisationsgränser. Studien baseras på flera metoder, longitudinell ångärdssforskning, flerfallsstudie, systematisk litteraturgranskning (SLR), klassificerings- och regressionsmetod (CART) och metod kring artificiella nätverk (ANN). Tillvägagångssättet valdes på grund av de komparativa...
fördelar av flygplatsprocesser och operationer som erhålls för analysen. Inom ramen för avhandlingen betraktas flygplatser som komplexa system, där det interorganisatoriska mät- och styrsystemet operationaliserats med organisatorisk komplexitet, kontinuerlig förbättring och som ett socialt system.


Återkopplande och drivande mekanismer för dual styrning av samverkande prestanda associeras med fyra cybernetiska funktioner: identifiering, styrning, aktion och process. Vidare introduceras konceptet med reflektivt prestationsmätningssystem med allmänna förutsättningar för att underlätta samverkansbeslut. Studien avviker från tidigare forskning inom ledning och styrning såsom förlängd verksamhet, virtuella företag, och integrerade mät- och styrsystem genom att undersöka specifika mät- och styrsystem funktioner och belysa avvikeln inom komplexa system med många intressenter. Dessutom lägger studien en grund för att ompröva hur framtiden för interorganisatorisk mät- och styrsystem bör utformas.

Nyckelord: Prestationsmätning, Flygplatsverksamhet, Samverkansbeslut
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Stockholm, the 10th May, 2017
Simon Okwir
List of appended papers

The thesis contains a cover essay and five appended papers.

Paper 1

Paper 2

An earlier version of this paper was presented at EurOMA Conference, Palermo, Italy, 20-25 June 2014
To be submitted to Production Planning & Control Journal.

Paper 3

An earlier version was presented at the Performance Management Association (PMA) conference, Edinburgh, Scotland, 26-29 June 2016 and invited for inclusion in a special issue on PMM – *Towards a Theoretical Foundation for Performance Measurement and Management.*

Paper 4

Paper 5
Okwir, S., Prediction of Airport Infrastructure performance with collaborative measures: Studies from Barajas Airport. *(Working Paper)*
To be submitted to Journal of Air Transport Management.
Additional publications (not appended)


Distribution of work among authors

Cover essay
Author: Simon Okwir

Paper 1
Authors: Corrigan, S., Mårtensson, L., Kay, A., Okwir, S., Ulfvengren, P., & McDonald, N.
Deliverable in MASCA EU funded project, Okwir joined the on-going project when he commenced his PhD studies. He contributed with state of art theory for this paper.

Paper 2
Authors: Okwir, S., Ulfvengren, P., Kaulio, M.
Simon Okwir planned the study, collected data, and was a main author and wrote the most of the paper. Ulfvengren and Kaulio contributed by reading the text and giving comments.

Paper 3
Authors: Okwir, S., Angelis, J., Ginieis, M., Nudurupati, S.
Simon Okwir planned the study and idea, and wrote the whole paper. Jannis contributed by reading the text and giving comments, Ginieis contributed to the method section and Nudurupati contributed by reading and writing and giving comments.

Paper 4
Authors: Okwir, S., Ulfvengren, P., Angelis, J., Ruiz, F., & Guerrero, Y. M. N.
Simon Okwir planned the whole study, collected data and was the main author. The rest of the authors contributed by giving comments on parts of the paper.

Paper 5
Authors: Okwir, S.
Simon Okwir planned the study and collected data, and was the sole author.
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Foreword

6th July 2012

Vignette

Today, 6th July 2012, Madrid–Barajas Airport is expected to handle at least 800 arriving aircraft and more than 600 departing aircraft. 50% of these arrivals have a short Turnaround Process (TAP). Normally, a typical TAP ranges between 45 minutes and 2 hours. There are several actors involved in the turnaround process. These include Air Traffic Control (ATC), which controls the supply and demand of the runway, the airport hub operations team, which has over 50 staff members with giant screens and networked telecoms to dispatch airport resources such as staircases, pushback tugs and runway airport shuttles. The main ground-handling company offers airside services to more than 70% of airlines including cleaning, catering, and fueling, supplied by various companies. The ground-handling company alone has up to 200 turnaround co-coordinators who conduct all turnaround processes, ensuring smooth and on time operations. In addition, the baggage handling companies are expected to handle at least 3,200 bags on departure flights and 52,000 bags on arrival. Normally, of all bags handled each day, over 1,200 should be delivered to connecting flights during the turnaround process. It is an operational hitch that nearly 100 bags miss targeted flights, and are declared delayed, lost, or damaged. Finally, there are over 100 airline companies that have contracts with the airport management for slot allocation.

Given that the airport operates with scarce resources and with only four functional runways, two of which are closed in the evenings for noise abatement purposes, the airport lies at the lower end of its operational capacity. It is being realized that important metrics such as on-time performance, lost baggage complaints, taxi time, fuel, CO2 emissions and runway congestion vary on a daily basis. With the recent initiatives from regulators, the airport management agrees to implement a collaborative Performance Management System (PMS) called Collaborative Decision-Making (CDM). Regulators state that CDM integrates all processes in real-time, improves levels of situation awareness and optimizes operations to reduce taxi times, which translates to lower fuel costs, lower CO2 emissions, optimal use of airport resources and stable runway throughput. Given the interdependency and complexity of the airport operations management and a diversity of actors who have different interests and views, it is therefore worthwhile to investigate how actors manage the demand and supply of runways through a collaborative PMS.

1 The thesis employs the use of vignettes (Carlile and Christensen, 2005) to represent the veracity of empirical voices as descriptive illustrations of what the researcher saw, read and heard over a period of four years within the airport’s operations management. Three vignettes have been used in the cover essay.
1. Introduction

This chapter provides a background to the research problem, focus of the thesis, research questions and the overall thesis structure.

1.1 Aim and background

This thesis examines Performance Management (PM) practices in an inter-organizational setting. The main aim is to develop a framework for actors who manage operations using complex collaborative Performance Management Systems (PMS) (Busi and Bititci, 2006; Pekkola and Ukko, 2016). Within the context of this study, collaborative measures are observed to be a result of interdependent roles that are integrated and interwoven simultaneously into partners and/or ingrained in operating processes along the system value stream. Consequently, collaborative measures are essential to system interoperability and functionality (Alfaro et al., 2009). Creating a framework for managing through collaborative measures (i.e., discerning collectively what is measurable, observable, and controllable for a functional, collaborative PMS), actors face misalignment between inputs and outputs (Melnyk et al., 2014; Pinheiro De Lima et al., 2013), but in Performance Measurement and Management (PMM) literature, this is seldom discussed.

This study suggests that as actors adopt PM practices for inter-organizational performance, it is essential to investigate underlying conditions that sustain a collaborative PMS to understand factors that delimit operational capabilities. Based on the theory of feedback and feedforward as a dual-control mechanism, this thesis investigates challenges related to inter-organizational performance that hinder efficiency and effectiveness in complex, multi-stakeholder settings.

As a body of literature, PMM has evolved. The publication Relevance Lost: the rise and fall of management accounting (Johnson and Kaplan, 1987) raised doubts about the significance of PM, both in academia and among practitioners. The paper ensured that academics put new innovative perspectives on PM practices, and as a result, PM has not only become a common mechanism for managing business performance (Hoque, 2014; Micheli et al., 2011; Micheli and Mari, 2014), it garnered interest from a variety
of fields such as accounting (Otley, 1999), management (Atkinson and Hammersley, 1994; Pinheiro De Lima et al., 2013), public and nonprofit organizations (Micheli and Kennerley, 2005; Moxham and Boaden, 2007) and operations/process management (Bititci et al., 1997; Bourne et al., 2000; Neely et al., 1995). This multi-disciplinary perspective led to an enormous amount of academic and practitioner research on PMM (Bititci et al., 2005a; MacBryde and Mendibil, 2003; Melnyk et al., 2014).

A major development step came with the introduction of Balanced Score Cards (BSC) from Kaplan and Norton (1992), which streamlined complex organizational structures into four parts. BCS and several other PM frameworks played a role in determining the reasons some organizations succeed and others fail (Hoque, 2014). However, weaknesses associated with these frameworks were tested by Bititci (1997), which led to collaborative frameworks that focus more strongly on stakeholder needs (Mendibil and Macbryde, 2005). For example, the Integrated Performance Measurement Reference Model and the Performance Prism were developed with a recognition that many businesses serve a range of stakeholders and to separate financial and non-financial measures. As a result, organizations that focus on assessing departments independently started examining holistic measurement, arousing curiosity among researchers about how a collaborative PMS should be designed and managed (Bititci et al., 1997; Pekkola and Ukko, 2016; Pun and White, 2005).

Business continues to change. Trans-organizational communities of practice and collaborations occupy a significant part of existing PM practices. With the new pace of environmental change, traditional hierarchical organizational forms, in which decision-making is centralized, are gradually being replaced with new, collaborative-based organizations in which decision-making is distributed. Examples include the emergence of global, multicultural networks in expanding organizations, the rise of service-based transformations (servitization) such as Rolls Royce, which no longer sells jet engines but power-by-the-hour, the shift from manual work to knowledge-based work (Bititci, 2015), and the changing nature of work from autocracy to netocracy. With such transformations, PMM literature has explored collaborative PMS through Extended Enterprise (Braziotis and Tannock,
2011; Ferreira and Otley, 2009; Lehtinen and Ahola, 2010), but recent research (Ashmos et al., 2002; Melnyk et al., 2014) recognizes that some organizations in operations management operate in complex environments, with multiple stakeholders who are operating with specific interests and differing views, which adds another dimension of what it means to collaborate in such settings (Busi and Bititci, 2006). Operations appear to exist sequentially, but with high complexity and uncertainty. In such settings, collaborating actors require quick decision-making, which depends on creating value. They are also involved in coopetitive relationships. Such settings, including airport operations, emergency health care units, and railway track systems, are affected by top-down change processes, regulatory aspects, government, and to some extent, the wider system, which makes most existing collaborative PMS frameworks limited in catering to the demands of every actor. This logically creates tension between collaborative, strategic intent and collaborative approaches, suggesting that an imbalance exists between interests and viewpoints. In such settings, PMM is falling out of touch with evolving trends in organizations, breaking alignment between collaborative strategic intent and collaborative operational measurement (Melnyk et al., 2014). This on-going challenge has always prompted scholars of PMM to question how collaborative performance measures exist in an inter-organizational context, and how management should administer them (Agostini and Nosella, 2015; Busi and Bititci, 2006).

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Coopetition means the simultaneous existence of cooperation and competition. The term emerged in strategic management literature in the 1990s as a shift from win-loss to win-win strategies (Dyer and Singh, 1998; Mina, 2011), with introduction in research by Brandenburger and Nalebuff (1996).
1.2 The research problem

The research problem being examined is the systematic administration of collaborative measures due to misalignment between collaborative inputs and collaborative outputs. Actors do not respond to measures similarly, which counteracts system goals, and consequently, challenges due to interoperability and functionality become critical (INCOSE, 2015; Alfaro et al., 2009; Nudurupati et al., 2015; Toor and Ogunlana, 2010). Three challenges are discussed that affect administration of collaborative measures in complex, multi-stakeholder settings.

First, is the challenge of many actors and processes, which depend on each other to create value. Since many components depend on each other for the system to function, complexity is common due to the range of interacting elements. Complexity breeds new behaviors, which can be unpredictable and ambiguous. Hence, it is particularly problematic in a system of systems environment to manage using collaborative measures for the system’s interoperability and functionality due to organizational complexity (Berman and Jones, 2016; Castro and Almeida, 2017).

Second, is the challenge of how to attain common strategic alignment with a diversity of actors. Although measures link operations to new business strategies, such alignment is complex for collaborative measures since the process for continuous improvement is hindered (Bond, 1990; L. Brown and Eisenhardt, 1997). Consequently, the question is what will be the focal business, and who will own the data to set the new measures.

Third, is the challenge of a complex social system. SoS environments are unique since they are highly technical but also depend greatly on a social component, and the social component must adapt to the technical side of the system (Schein, 1996). This creates disparate institutional logics and various maps within management in terms of how collaborative measures should be managed (McDonald, 2015; Carlsson-Wall et al., 2016). In this context, intra-PM dimensions are applied for dual control of feedback, but they conflict, creating incongruences when determining how to keep the system both strategically and operationally efficient. PMM literature should identify
performance guidelines for inter-organizational PM to maintain a collaborative PMS that is dynamic and responsive.

1.3 Approach and focus of the thesis

To explore the feedback mechanism of many actors, this thesis combines two theories—PMM theory as domain and system theories, and Cybernetic Control Theory (CCT) as a method theory (Lukka and Vinnari, 2014, 2016). This approach enhances the current debate on the value and usefulness of employing method theories in research, and the reasons for contributing to mid-range theories such PMM (Laughlin, 1995).

The challenge of feedback mechanisms is explored empirically using airport operations as an SoS. The focus is investigating operations management of the Turnaround Process (TAP) as a System of Interest (SoI). TAP is a classical part of the airport system, which is the time between when an aircraft touches down to when it takes off. TAP functions primarily on the supply and demand of the runaway, and involves many actors. The empirical focus is therefore limited to TAP by examining the apparent nature of feedback as a required practice of inter-organizational performance.

This thesis explores intra-PM dimensions to examine them as inter-organizational PM features. As a result, management of collaborative measures in this study is operationalized using three dimensions: organizational complexity, continuous improvement, and social systems.
1.4 Purpose and research questions

The purpose of this thesis is to investigate PM dimensions how they affect the management of collaborative measures in a quest to attain better operational performance for inter- organizational PM. To achieve this, the thesis addresses the following Main Research Question (MRQ):

**MRQ: How do actors manage operations through inter-organizational performance measures?**

To answer this question, the thesis addresses three sub-questions all of which are set in the same airport context. It is important to examine and understand the context in which SoS operate regarding how actors collaborate. Accordingly, the thesis explores this context by investigating sources of complexity that affect inter-organizational PM. Hence, the first sub-question is:

**RQ1.1: What are the sources of inter-organizational complexity?**

Answering the main research question involves exploring how collaborative measures are being managed during continuous improvement. This is also because continuous improvement is a management concept that every actor performs. However, within a network of actors, since it requires unique features such as collaborative decisions to keep a system both operationally efficient and strategic. Hence, the second sub-question is:

**RQ1.2: How do actors collaborate while continuously improving?**

Since organizations operate under social-technical processes, and people drive processes that deliver performance. The social element is more convoluted than the technical part. This is because the technical element is easily feasible than the social part. The social system adapts. Hence, the third sub-question is:

**RQ1.3: How do social aspects affect inter-organizational performance?**
1.5 Disposition

Chapter 1, the introduction, consists of the background of the research problem, focusing on the thesis and research questions. Chapter 2 presents airport operations and why they implement a collaborative PMS. Chapter 3 explores the PMM literature as a domain theory, and CCT theory as a method theory. Dimensions being explored—complexity, continuous improvement, and social systems—are also presented. Chapter 4 presents the research strategy and methods used in appended papers, and Chapter 5 presents paper summaries. Chapter 6 answers the research questions and proposes a cybernetic framework for inter-organizational PM. Chapter 7 concludes with influences on theory and practice, with anticipated future research. Figure 1 illustrates the thesis’ structure.

**Figure 1: Thesis structure**
2. Airport Operations

This chapter presents a historical account on why airports started implementing a collaborative PMS. It covers reasons for its adoption, challenges encountered and benefits to actors. The chapter ends with the second vignette which reflects on the implementation of a collaborative PMS at Madrid-Barajas airport.

2.1 A historical account for collaborative PMS

In the beginning of 2000, the European Commission (EC) launched the Single European Sky (SES) project. The initiation of SES was based on the conclusion from experts that air transport in Europe had started to growing much more quickly than the airport systems’ capacity could handle. It was demonstrated through the uplift of globalization over the passing years, how the European aviation growth has experienced increasing demand for tourism and trade. Today, it is estimated that the European air navigation service providers will be handling almost 11.5 million aircraft movements every year and it is predicted that by 2020, almost 40,000 flights will be flying per day over the Eurozone alone (Eurocontrol, 2012). This created a crisis within modern commercial aviation in Europe (Wu and Caves, 2002), as traffic overloads and excessive congestion started to be noticed at major airports, including noise and CO₂ emissions.

Given the critical role that airports play in the economy, regulators at EU agreed to focus more on implementing sustainable strategies for aviation. In February 2007, the Single European Sky Air Traffic Management Research Joint Undertaking (SESAR-JU) was founded to be responsible for all the research and new technologies needed for system change in Europe. This has placed significant pressure on different aviation companies and airports in Europe to provide better products and services to handle large traffic transfers. SESAR has gone through a series of milestones in producing first class technology that will facilitate the use of a single sky. However, system changes to build a single sky still face major challenges such as harmonizing the European skies with different national borders, security risks as many national Air Traffic Management (ATM) systems are operated by the national army, and harmonizing the entire operations management of European

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airports both on ground and in the skies. Aside from reducing delays and congestion problems, SES is to remedy the challenge of non-alignment of ATM systems, replace outdated technology, defragment the fragmented and/or uncoordinated air flow control.

Airport actors such as ground handlers, airlines, air traffic control and airport management, are required to implement new standards to optimize operations on the ground for less traffic on runways and also for route management in the skies. One of the standards needed for single sky is Airport - CDM (Collaborative Decision Making). The EU looks ahead to have all European airports become CDM compliant by 2020. The CDM initiative is also seen as a viable tool for improving the ATM quality and increasing the situational awareness in the European airports.

As airports try to meet EU demands with new standards. The airside operations as a sub unit to the entire airport is key. Airport actors need collaborate, the need for airports to collaborate interferes with business aspects as several competitors need to share information and collaborate for the wider system goals. Therefore, the research problem exists as a result of a systematic change seen at three different levels, i.e., at European level, industry level and process/operations level. The first two levels frame the research problem while the last level is the unit of analysis. Specifically, implementing new technologies in airports to facilitate system wide changes and integrating system objectives with local objectives.

2.2 Airport – Collaborative Decision Making (CDM)

A-CDM is a new collaborative PMS created within the framework of the single sky project. A-CDM aims at reforming and improving the European aviation by optimizing scarce airport resources’ use, such as runways, terminal gates. A-CDM facilitates route segmentation in the sky. It considers issues of air traffic flow to take-off slot allocation with an operational methodology in the turnaround, i.e., from “first come-first served” to “best planned - best served”. A-CDM facilitates Eurocontrol objectives to rely on much higher predictability of flight departures in order to manage air traffic with higher capacity across Europe.
As an implication, A-CDM presents a challenge to airport organizations: to find new ways to collaborate with competitors to implement and manage inter-organizational on-time performance measures. CDM scenarios presuppose various levels of collaboration between stakeholders, such as enhanced distribution of information, ensuring that all actors have the picture as clear as possible as a lowest level, redistribution of decision-making responsibility with the delegation of responsibility for allocating scarce resources to users as the highest level. It is notable that multiple actors involved in the CDM implementation process are bound with relationships of competition and cooperation at the same time. This makes the fabric of their interactions complex from the strategic management perspective. As a collaborative PMS, if well implemented, it is envisioned that CDM provides distinct benefits to airport actors. Table 1 shows these benefits for each actor.

Table 1. CDM benefits for airport actors (Source: Eurocontrol)

<table>
<thead>
<tr>
<th>Airports</th>
<th>Airlines</th>
<th>Ground handlers</th>
<th>Air traffic</th>
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<tbody>
<tr>
<td>More capacity and increased revenues</td>
<td>Shorter holding times and taxi times</td>
<td>Better planning and usage of airport resources</td>
<td>Improved slot management</td>
</tr>
<tr>
<td>Airport image</td>
<td>Lower fuel costs</td>
<td>Shorter turnaround activities</td>
<td>More predictable flights</td>
</tr>
<tr>
<td>Better operational efficiency</td>
<td>Reduced delays and improved customer satisfaction</td>
<td>Increased productivity</td>
<td>Better pre-departure sequence</td>
</tr>
<tr>
<td>Airport punctuality</td>
<td>Increased capacity with shorter flights</td>
<td>Client satisfaction</td>
<td>Better usage of runway capacity</td>
</tr>
</tbody>
</table>
2.3 Challenges in airport operations

Network objectives (EU) Vs airport (local) objectives

According to the proposed European Master Plan (EUROCONTROL, 2015), A-CDM if well implemented on European airports, the envisioned benefits are to be realized both at airport level and at European level. At airports level, benefits such as enhancement of runway throughput, proper use of resources, would contribute to the environment benefits such less noise, less carbon emissions and capacity which are wider network objectives. However, network and local benefits can only be realized with several airports being CDM complaint. This makes early adopters constrained as they can’t realize benefits faster since they are affected by system wide implementation.

To this day, the objectives to establish indicators for performance measurement has been divided as follows:

1. Generic objectives at European level for all CDM airport partners.
   These are in the four main areas, i.e. Efficiency, Environment, Capacity and Safety.

2. Specific objectives to establish indicators for each airport actor linked to at least one system objective.

Therefore, aside from the conflicting views, priorities and interests among actors, the wider regulatory objectives hinder local objectives on finding common indicators for the wider system.

A shift from hierarchal to collaborative leadership

Experiences from several CDM airports has shown that collaborative leadership is a vital element for turnaround effectiveness (Crespo and de Leon, 2011). This would reduce the existing imbalance in power between actors, create a balanced network that considers demands, views and interests from distinct actors. Collaborative leadership would manage change by focusing on the big picture (system goals) rather than single actor interests. It then follows that administration of collaborative measures is distributed and collaborative rather than hierarchal. As such, airport operations are now being
challenged what kind of leadership would locally administer a system wide collaborative measurement system.

**Deviations from regulatory standard procedures**

To avoid risky implementations, CDM implementation manual recommends that airports should involve all partners right from the start. But experience from several CDM airports has shown that implementation that was successful kicked off with few major actors then other actors were invited along the process. It appears that new adopters have been challenged with ambiguity risking high investment in the implementations following standard procedures compared to the reality. This has resulted in longer periods of CDM implementations at various airports.

**Blame culture**

Implementing Airport CDM comes with several demands which will require actors to adopt to new ways of work, such as new forms of sharing information, first ready-first served methodology. Because of these new changes, actors have to sacrifice their interest for others. For this, there is professional criticism among airport actors themselves. During the interaction with turnaround participants, this was mostly observed with pilots and ground handlers in the CDM network. Pilots claim that CDM operations are ATM driven which is not good for airlines, while ground handlers claim more work is now being put before them during ground operations. Each actor had a different view on CDM operations. As result, the blame culture appears to be one of the main challenges hinders poor implementations across.

Finally, A-CDM has a broad covering sphere which considers many actors for its functionality. Within the context of this thesis, the following section sets borders for a unit of analysis which is local CDM in the turnaround operations.
2.4 Research context

Figure 2 show the overall unit of analysis for the thesis. For the purpose of the thesis, airports were preferred as they covered all three conditions that were set for a suitable research context for the thesis. First, the operations management of airports is assumed to be complex as it involves many actors and different systems that are interconnected for the overall functionality. Second, airports are more likely to implement collaborative approaches within all segments of their operations, in business, operations, security and safety (Nucciarelli and Gastaldi, 2009). Third, the turnaround process (TAP) would be picked as the System of Interest (SoI) as a sub unit of the larger airport. By adopting the TAP system as the system of interest, the thesis was able to study the management of a collaborative PMS as it is shared between several actors in the TAP as shown below.

![Diagram of the Turnaround Process and its actors]

Figure 2: System of Interest: The turnaround process and its actors
Implementation of collaborative measures at Madrid–Barajas airport

Vignette 2

Madrid-Barajas Airport (MAD) is currently Europe’s seventh busiest airport with over 40 million passengers annually. The airport recorded almost 350,000 movements in 2014, which is 1,000 flights a day. With limited capacity, airside congestion became an issue. The airport management at Madrid-Barajas Airport agreed to adopt a new Performance Management method called CDM†. The airport management office at AENA (Aeropuertos Españoles y Navegación Aérea) began the CDM project as a focal point of resources and support for implementation. AENA was provided with a CDM implementation manual to assist with the process of implementation from EU regulators. AENA was faced with the challenge of convincing over 20 actors in ground handling operations and more than 100 airline companies who operate at the airport to be part of the project. As a norm, educational materials were printed and distributed, websites were launched and actors were initiated at several workshops. At first, everything went smoothly. However, although the stated objectives and benefits of the CDM were clear to each actor, there was some resistance as actors started questioning the reality of benefits of CDM. Several actors could not see the use of CDM as a system that would enhance the efficiency and effectiveness of operations. After a period of six months, the airport management took the lead in advancing new phases of implementation. First, organization meetings were held with a few big actors in the network. Once this was achieved, other actors were invited to attend subsequent meetings. After two and half years, all actors were on board for full implementation, Madrid airport was certified as a CDM airport in late 2014.

† Airport CDM was locally implemented at Madrid airport from December 2013, with the network integration established operationally in June.
3. Theoretical framework

This research is positioned within PMM literature as a domain theory and Cybernetic Control Theory (CCT) as a method theory. The chapter defines and describes PM practices in airport as a System of Systems. The chapter also makes an inquiry into CCT. The chapter also covers PM dimensions that are being examined. The chapter ends by discussing the operationalization of collaborative measures within a system of systems.

3.1 Performance Measurement & Management

According to INCOSE (2015), A System is defined as an integrated set of elements, subsystems, or assemblies that accomplish a defined objective. These elements include products, processes, people, information, techniques, services, tools and other support elements. A System of system is a System of Interest whose elements are managerially and/or operationally independent systems. These interoperating and/integrated collections of constituent systems usually produce results unachievable by the individual systems alone (Checkland, 1994; Gorod et al., 2008). Given that the operations management in airports is highly networked with many sub-systems, with each sub system having its own organizational structures. The composition of sub-systems is what forms a system. Given that airports consists of several parts which are interdependent to facilitate the functioning of the whole system, the TAP covers all conditions as a SoS. One way to understand a SoS is to apply the reductionist approach. This is where parts of the system are broken down to manageable or understandable parts. However, with the reductionist approach, a lot of complexity is absorbed which is ultimately important to understand the system functionality. As such, SoS require a holistic approach to sorting out such complexity. The tension between the reductionist approach and keeping the holistic approach should be dynamically managed through linear and interactive processes.

Dahmann (2014) identifies six challenges that influence a SoS: authorities, leadership, constituent systems perspective, capabilities and requirements and autonomy.

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The term “cybernetics” originates from a Greek word, kybernetes, which literally means “steersman” or “governor.”
testing and validation. To achieve the purpose of this thesis, SoS challenges are discussed with regard to their implication to inter-organizational PM.

The first challenge is connected with SoS authorities. In SoS, the organization structure does not come under a single authority. Each part of the system, such as users, business processes or stakeholders, tends to be managed by its own local authority. However, for the entire system to be functional, all parts need to be integrated with collective aims even when they conflict with those of individual parts in the system. The airport exhibits a similar situation. The TAP as a SoS has many parts that allow the airport to remain functional. When it comes to improving airport capacity, the overall performance of an integrated sub units is needed so as not to coincide with the views of several others.

Second, is the challenge of leadership. The lack of a collaborative leadership breeds organizational plurality in management styles. With diversity in functions, roles and processes, incentives for the whole system are influenced.

The third challenge is the constituent systems perspective. This perspective deals with incumbent parts of the system that have to deal with incorporating new processes and new standards. Many resources in the system were developed for different reasons in the past, but due to advancement, new processes leverage on old components to meet the requirements for new system objectives. As such, there could be a mismatch which then poses issues for interoperability.

The fourth challenge is capabilities and requirements. The new required capabilities are those that are needed reach system goals. However, at local level, actors operate with different capabilities for the system. For this, the SoS will have to find alternative ways to meet the gap between what is required and what exists in terms of know-how. For an airport, the management of PM for turnaround faces similar challenges. First, there is a lack of capabilities to manage system performance of turnaround and such capabilities are not found within a single actor.

The fifth challenge is about autonomy: interdependencies, and emergence. Since SoS constitutes many parts which are independent, this could be a source of technical issues for the whole system. Since the system is open and dynamic,
interdependences of other parts affect the system with emergent new behaviors. As such, the system is not autonomous for control.

Finally, the sixth challenge is testing, validation and learning. To conduct validation for new standards in a SoS, there is always an end-to-end validation for all parts in the system. Because the system is large and composed of several part, each part has to be validated and tested to assess the level of performance or what is needed. For instance, in an airport, new metrics have to be tested for all turnaround actors if they do not hinder operational requirements for a few. The challenges presented above are those that foster System Interoperability (SI). SI relates to system integration for functionality. It is the integrated coordination of all components in the system. However, interoperability is always challenged by both social and technically related issues (Castro, 2015). As such, for a system to function it will acquire novel principles that will define the new procedures since these dimensions lie beyond the technology layer.

3.2 Performance Management Systems

There is limited evidence on how a shared PMS should be administered in relation to the characteristics of SoS as described above. Therefore, it is important to understand several aspects of inter-organizational PMS. According to Bititci (2015), PMS is defined as a “process of setting goals, developing a set of measures, collecting, analyzing, reviewing and acting on performance data”. The practical implication of the theoretical definition of PMS as a process becomes vague under SoS with collaborative measures. Intrinsically, PMS of SoS is one that requires feedback and feedforward control systems to maintain interoperability in such a system. For feedback and feedforward to occur, there must be a performance management process to allow the context in which Performance Measurement will be conducted.

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5 In PMM, measures provide timely and accurate feedback (Neely et al., 1996). The concept of feedback is defined by Schwaninger (2015) as a process in a system by which an outcome variable is redirected – normally via a control system as an input, such that the object system’s behavior changes.
This means that management precedes measurement, as such, PMM is an inseparable process as the two processes cannot be separated if objective/effective measurement is to be established.

Other unique characteristics for effective PMS would be that measures should form an integrated entity to support each other, and that measures should provide a platform for continuous improvement (Folan and Browne, 2005; Halachmi, 2005; Neely, 1999; Otley, 1999). However, contrary to the former, for collaborative measures, such realities make SoS imbalanced as collaborative measures lack a collaborative decision making for design, management and use. In discussing a conceptual model for PMM of a cluster using Balanced Scorecard, Cesar Ribeiro Carpinetti et al. (2008) explains that the need for collective efficiency and types of relationships are among the determinants of quality of measures. Therefore, extending PMS to SoS as a collaborative PMS means extending PMM dimensions which are discussed in the following section.

3.3 Collaborative measures dimensions

A set of three conceptions for exploring collaborative measures as an inter-organizational were selected to position the investigation of this research, namely, organizational complexity, the process of continuous improvement and PM as a social system. This thesis explores these PM dimensions to be examined for inter-organizational PM. The rationale behind these dimensions is derived from the state-of-the-art in PMM literature as they were repeatedly discussed by many authors (Bititci, 2015; Busi and Bititci, 2006; Castro and Almeida, 2017; Harkness and Bourne, 2015; Pinheiro De Lima et al., 2013). The following section discusses these dimensions in detail.
• **Dimension One – Organizational Complexity**

The first dimension being explored for inter-organizational PM is organizational complexity. PMM literature mostly views complexity as a result of the interaction with the wider environment, such as markets, customers, and changes in technology. PMM considers this environment complex as it dynamic and open. Since users respond to the wider pressures from the external environment, this creates an implication on the practice of measurement along the three process stages of PMS. This argument is partly in agreement with Harkness and Bourne (2015), who suggest that complexity is a barrier to the practice of performance, due to both the environment and a number of practical factors such as ambiguity, lack of control, unpredictability, and a lack of enough information that interacts in the system. After examining the literature, complexity is then explored as the interplay between what is measured (Micheli and Mari, 2014) and how it is controlled in SoS (Mol and Beeres, 2005; Canonico et al., 2015). This involves updating, analyzing, and acting on performance data (Bititci, 2015; Bourne et al., 2000; McAdam and Bailie, 2002).

Another reason for this argument is that complexity lies at the heart of organizations as they are continuously changing (Boulding, 1956; Roehrich and Lewis, 2014; Stacey, 2011). It then follows that the ongoing processes and functions in the internal environment suggest questions for inter-organizational PM. Organizational complexity is investigated by exploring the evolution map developed by Folan and Browne (2005). Specifically, the thesis explores the evolution of inter-organizational complexity as a major implication for PM.

• **Dimension Two – Continuous improvement**

The second dimension being investigated is the process of *continuous improvement*. According to PMM literature (Neely et al., 1997; Perkins et al., 2014), metrics and indicators give life to organizations. As better management practice, measures provide future trends, help to implement strategies and provide the power of communicating with measures for instance, creating continuous improvement’s capability to set new measures and so forth. Continuous improvement is vital practice for businesses as they need to
change dynamically (Brown and Eisenhardt, 1997). Continuous improvement considers using measures as a feedback mechanism to effectively improve processes, and whether measures are being used in the balanced manner (Bond, 1990; Olsen et al., 2007; Wu and Chen, 2006).

Continuous improvement also deals with organizational performance management that controls best practices to lead PMS to maturity. For example, while designing a model for profiling organizational PM, Jääskeläinen and Roitto (2015) show existing gaps in maturity model assessments. In other words, even during mature stages, many models concentrate on the design of PMS using performance measurement as a driver for continuous improvement. For this, even maturity models require measures for continuous improvement, which is a versatile practice and special action is needed to offer grounds for improvements (Elg et al., 2014).

Questions about this dimension include how the lifecycle of a PMS that transcends an organization exists with continuous improvement programs, i.e., from birth to maturity, and more specifically, how it will become a mature performance system using an inter-organizational approach. In this thesis, continuous improvement is therefore investigated and discussed by exploring a theoretical model developed by Pinheiro De Lima et al. (2013) which is influenced by the work of (Folan and Browne, 2005). The model is applicable to managing operational strategy, of which continuous improvement is one of the core elements. Specifically, this thesis explores whether and how double and single loops can be applied with this model in the light of collaborative measures. Papers 4 and 5 examined this dimension.

- **Dimension Three – Social System**

The third and last dimension explores *social system*. PMS are social – technical systems. Conventionally, previous research shows that organizations are social systems (Johannessen, 1998). In PMM literature, managing performance, the universal structure underpins people, processes and performance. For this reason, there is a need to understand the social component, which is currently being investigated as social system. Within the context of this thesis, there are two reasons for investigating social system. One is that, for inter-organizational PM, measurement occurs within several
social organizations with the managerial support of both technical and social controls (Bititci, 2015). Technical controls deal with effectiveness and are considered to be the most objective. Social controls deal with people. Most managerial challenges for collaborative measures seem to germinate from managing social controls, especially when different departments and organizations have different social logics on what to measure and how. Secondly, previous research also confirms that PM as a social system is one of the centric points for a holistic research framework for performance measurement (Bititci, 2012). In addition to this, McDonald (2015, p. 197) demonstrates that “People operate as part of a social system, managing the dependencies within the process system”. Thus, the social system is as much a part of overall system functionality as any other part. In sum, social system creates important implications for inter-organizational PM. This dimension is explored in two ways. Paper 1 explores dimensions using the operational framework for system analysis proposed by McDonald (2014), while Paper 3 explores dimensions using a theoretical framework that typifies both social and technical controls.

3.4 The role of Cybernetic Control Theory

Cybernetics is a discipline that has been studied to explore governing systems, and their constraints, structures, and capabilities. Since its establishment in the 1940s, cybernetics has been explored in many fields, such as biological systems, technical systems and social systems (Schwaninger, 2015). Wiener (1948) defines cybernetics as the science of ‘control and communication’ in animal and machine. In management, a foundational work in applying cybernetics to organizations by Beer (2002) introduced the viable system model, a model that enhanced the effectiveness of collaboration. In his work, Beer discusses the intrinsic control in real-time by bringing cybernetics to industrial management, defining management as the “science of effective organization”. Ultimately, management cybernetics applies the theory of cybernetics control to organizational structures and management in any institution(Beer, 1986; Croucher, 1981). Cybernetics form the basis for the cycle of a cybernetic control and management, to observe, capture and monitor governing and control systems for performance. The cycle is
composed of four elements that ensure feedback and control, i.e. sensor, commander, actuator and process. These elements influence each other through a chain and cause effect.

As a domain theory, CCT is then adapted to influence inter-organizational management in order to have a central decision authority. Christopher (2011) argues that a principle of cybernetic science is that systems have the capability for self-control in a system. In doing so, he explains that the controller is just as effective as the decision-maker. To elaborate more on this, cybernetic functions are discussed according to Leveson and Heimdahl (1994) as follows. The sensor element which is concerned with error detection in the system behavior, gives feedback to control system. According to the circular property of cybernetics, this allows for an explanation of a system from within. The actuator manipulates the process there by executing commands. The process is the interpreter to the sensor, which provides immediate and constant feedback and the desired output, which is repeated in a continuous manner with inputs and outputs. The controller performs the corrective action where feedback is provided via controlled variables. Figure 3 shows the basic cybernetic cycle between inputs and outputs.

![Figure 3: Basic cybernetic control cycle (Leveson and Heimdahl, 1994)](image)

Malmi and Brown (2008) propose the idea that cybernetics is all about processes and change which involves uncertainty. Such processes evolve into
adaptation and then growth. For instance, the feedback loops account for the regulation and the efforts of the system to maintain a state of equilibrium to reach a target. Based on this understanding, this thesis argues that feedback is a function of specific cybernetics roles which assist managers with explicit information for inter-organizational PM. This thinking is also supported by previous research in PMM literature. For example, while developing a cross-organizational methodology, it was found that PM should be specific to business units (Kaplan and Norton, 2000; Neely et al., 1996; Bititci et al., 1997).

In other areas of PMM literature, cybernetic structures have been adapted, such as Bititci and Carrie (1998) who adopted the viable systems model and identified cybernetic thinking for a business approach between parties (Bititci and Turner, 1999). In other areas of operations, previous research has applied cybernetic controls to link shop floor process to strategic outcomes (Chenhall and Langfield-Smith, 2007), which allows managers and shop floor workers to engage in critical decision-making along the value chain (Bititci et al., 2005). While exploring the use of PMS in the public sector, Spekle and Verbeeten (2014) critically discuss the role of cybernetic incentives in contracting and their role in aligning goals with objectives. Cybernetic controls have also been mentioned in connection with hybrid PMS, where measures enable the quantification of phenomena, generate standards and enable a feedback mechanism which allows modifications in a system (Malmi and Brown, 2008).

The chain and cause effect

In cybernetics, feedback occurs when the outputs of a system are re-routed back into the system as inputs. This is called the *chain and cause effect* (Wiener, 1948; Beer, 1952). The challenge of feedback is either negative or positive depending on the type of error that cybernetics is tasked to patrol and control (Steer, 1952). Feedback in cybernetics is always assumed to be negative, hence correction is desired (Folan, 2002). Controlling performance using cybernetics always falls back to a central factor which is error correction. As articulated by Lehtinen (2010), cybernetics is all about what one system does to another in order to control. This means that the first system in the series influences the second system to form a chain and cause effect (Dormer and Gill, 2010; McAdam and Bailie, 2002).
In a similar manner, for inter-organizational PM, collaborative operations are treated as inputs and collaborative decisions as outputs. Most importantly, if a feedback loop is to be governed in a balanced manner with all actors inclusive. Feedback in cybernetics appears to be patrolled by all actors’ efforts as one system to determine the central or common measurement and management. This means that the chain and cause effect should be emulated and reproduced in such systems. If this is accepted to be the case, this thesis proposes that a circular feedback loop is applied in a similar manner in line with organizational cybernetics as explained by Beer (1986). Inter-organizational PM could be corrected and maintain a central decision-making authority to allow inter-organizational configurations. Customarily, such an analysis of the system should be done regularly to allow the collaborative PMS stay dynamic and responsive.

It then follows that, measuring system performance and managing comes within as self-organizing subunits. Collaboration between actors forms a loop of influence from one actors’ roles to another (Lehtinen, 2010). The notion of controlling performance informed by CCT becomes real with the collaborating actors who have specific roles within a system. These roles are to observe, capture, monitor and govern.

Overall, the ideology of cybernetic theory on performance measurements and management applies to almost every walk of life, from the body system which is homeostatically organized, into feedback loops that restore balance in body systems, to mechanical and medical inputs, such as cranes, cars and life support machines. Consequently, this makes cybernetic theory a better theory with which to explain the inter-organizational feedback challenge. In conclusion, inter-organizational PMM in cybernetics is a function of error correction. Hence, monitoring and measuring is a function of the single systems that are interconnected into a series of stringed systems to create a feedback loop mechanism that works on error detection and correction. As an implication, such a system corrects the challenge of feedback and a central decision-making authority could be ratified.
3.5 Inter-organizational Performance Management

For inter-organizational performance, Figure 4 shows the misalignment between inputs and outputs. The figure shows SoS challenges within a system of system that inter-PM must contend with. As such, the three PM dimensions are tested through four studies. CCT theory is then introduced as shown in the figure to bridge the gap between inputs and outputs as a method theory. The next section explains the framework detail.

For inter-organizational PM, researchers such as Yadav and Sagar (2013) and Folan and Browne (2005) have addressed the challenge of inter-organization PM through frameworks such as extended enterprises (Bititci et al., 2005b; Lehtinen and Ahola, 2010), integrated PMS, and collaborative supply chains (Busi and Bititci, 2006). However, these frameworks fail to capture all stakeholder demands which makes them limited, and some researchers question whether PMM is fit for managing collaborative measures (Lehtinen and Ahola, 2010). To this end, PM continues to be noted both in academia and in industry for being insufficiently dynamic and unresponsive (Melnyk et al., 2014). After examining the literature on system theory and PMM, this thesis is anchored on several studies. Firstly, Harkness and Bourne (2015) who suggest that there is a need to explore complexity so as to understand principal limitations in the use of PM in different operational contexts. Secondly, Nudurupati et al. (2015) who report on the use of measures to unlock collaboration in innovation, and Busi and Bititci (2006) who identify gaps in collaborative performance management. Thirdly, Bititci (2015) who distinguishes between managing technical controls and social controls in PMM. Lastly, Pinheiro De Lima et al (2013) and Folan and Browne (2005) who examine the theoretical framework for operations management of a system between inputs and outputs.

To construct a framework for inter-organizational Performance Management, collaborative performance in SoS is described in terms of interoperability and functionality of the system. Interoperability is the extent to which a system within a system can exchange data, interpret shared data and use them as information to support operations/management (INCOSE, 2015). Also, functionality of a system is typically expressed in terms of the
interactions of the system with its operating environment. With regard to six challenges shown in figure 4, interoperability is to what extent the system of systems manages these challenges. In addition, after examining the domain literature, among numerous PM practices, three PM dimensions were selected to be investigated for their functionality in inter-organizational PM. Finally, by inquiring the principles of CCT theory as a method theory (Lukka and Vinnari, 2014), it follows that with the four cybernetic roles found in the framework, it enables identification of role distribution among actors in the network for output loop to be completed. Figure 4 shows the framework in detail.

Figure 4: Framework for inter-organizational Performance Management
4. Methodology

This chapter presents the overall research design that was employed as a backbone for the whole thesis. The chapter also gives an overview of empirical context, methods selected and the quality of results.

4.1 Overall research strategy

PMM research is inherently linked to practice. In the debate of which theory to use as what is most suitable, Laughlin (1995) argues for mid-range theory which makes PMM theory as a mid-range theory more suitable. For this reason, the overall research strategy aimed to achieve the following. First, that it should analyze theoretical approaches in intra-PM as a system that transcends organizational boundaries and extend it to inter-PM. Second, that it should develop a tentative framework for managing through collaborative measures by adopting a meta theory. The exploration of CCT theory in this thesis advances our knowledge and sets a discussion on how the future of inter-organizational PM may incorporate a closed signaling loop, which opens up a window for the application of cybernetics controls in organizations (Beer, 2002; Kandjani and Bernus, 2012; Rosenblueth et al., 1943). This is a concept that has been asked for in PMM literature (Kandjani and Bernus, 2012; Malmi and Brown, 2008).

This research is based on four studies reported in the five appended papers. This process was achieved within a period of almost four years. During this time, the PhD student was employed at two partner universities and spent eight months at one of the airports as a visiting researcher. Studies I and II were conducted at a large airport in Sweden (Airport 1), Study III was a literature review of PMM as a domain literature, and Study IV was conducted at a large airport in Spain (Airport 2).

The two airports were selected as they had both declared their intentions to implement a collaborative performance management system. To begin with, Study I was conducted within the EU-funded research project Managing System Change in Aviation (MASCA). Study I served as empirical evidence
on the challenges that actors face when implementing collaborative PMS. This study is fully documented in Paper 1.

Study II was a case study, in which interviews were conducted at Airport 1. The purpose of this study was to identify complexity factors in the airport’s turnaround process (TAP) when viewed as a system of systems (SoS) so as to understand implications for Performance Measurement and Management. A total of 23 interviews were conducted over a period of nine months. Data collected from this study served as the data source for Paper 2. At the end of this study, key informants were again gathered in one room to validate the research findings. Study II contributed towards answering the first sub-research questions (RQ1.1).

Study III was a literature search. Having empirically examined the challenges met in implementing a shared PMS in study I and sources of complexity in study II, it was important to explore the domain literature. The sample data was collected from the Thomson Reuters and Scopus databases to explore what previous authors have documented on shared PMS and its complexity. The findings from this study were then documented and presented at the Performance Management Conference (PMA) held in June 2016 in Edinburgh. After a discussion and a peer review, mainly by academics in the area of PMM, the study was then expanded with a suggested theoretical model that typifies social and technical controls. This approach identified sources of complexity. This study contributed by answering the main research question in two ways. First, the three dimensions being tested were confirmed as part of the overall study through a literature search. Second, the study was expanded to answer sub-research questions RQ1.1 and RQ1.3, thereby shedding some light on the main research question.

Study IV was conducted at Airport 2. In this study, the PhD candidate was stationed at the airport and gathered operational flight data from the shared PMS within the turnaround operations segment. The study also developed following the realization that actors lacked a process for continuous improvement, and it was important that this study should seek to identify the usefulness of collaborative measures so that actors would be able to discern objective decision-making. The data collected from this study also served as a data source for Paper 4. Study IV contributed towards answering sub-
research question RQ1.2 by showing the process of continuous improvement by modeling. Within the context of this thesis, since the process of continuous improvement also includes an element of prediction, Study IV resulted in Paper 5, which reported on predicting collaborative measures.

The overall main methodological approach was qualitative, complemented with a quantitative investigation in Study IV. Hence, a multimethod approach to addressing the main research questions was employed, using longitudinal action-based research, a case study, a systematic literature review (SLR), the Classification and Regression Tree method and the Artificial Neural Network method. Due to the nature of the research question, it was worthwhile for it to be explored with a multimodal approach as this provided a unique advantage for comparison with different findings from other complementary methods. This approach of employing several methods is considered a sound and novel research approach (Brewer & Hunter, 2006; Goertz, 2016; Lauras et al., 2010). Alongside the multimethod approach, the thesis employed the use of CCT theory as a method theory to PMM literature as domain theory (Llewelyn, 2003; Lukka and Vinnari, 2014; Mayer and Sparrowe, 2013).

A method theory is interpreted by Lukka and Vinnari (2014) as a meta-level conceptual system for studying substantive issues in the domain theory with a particular set of knowledge on a substantive area in a field. CCT theory was selected as a domain theory for two reasons. First, from the formal definition of performance as the efficiency and effectiveness of an action, the theoretical foundations of PM lie in cybernetics and system control theories (Bitirici, 2015). Second, since the domain literature is challenged in terms of how to achieve strategic alignment through collaborative measures, CCT theory was a better choice as it would explain the feedback control between inputs and outputs within itself. Figure 5 shows the overall research process and how it answers the main research questions. It covers, the four studies and the airports studied.
4.2 Selection of methods

The study relies on a multi-method approach. The following section discusses each method.

*Study I – Longitudinal action-based research*

Study I was one of the cases in a multi-case longitudinal action-based research (McDonald, 2015). The project lasted over a period of three years and applied longitudinal action-based research (Pettigrew, 1990; Ruspin, 2002). Action research was introduced in the 1940s and has been used in many change environments. In his contributions to practitioners, K. Lewin describes action research as a creation of theory when a researcher actively participates in such platforms. Lewin further extended the idea to the present classical Lewinian model of research which stipulates research action steps such as planning, fact finding and execution (Adelman, 1993; Papanek, 1973).

Study I started with problem formulation from industry. The process of implementing collaborative measures and planning change was planned with multiple data collections with no chronological sequence but rather an abductive learning cycle with multiple iterations. Data collection methods such as semi-structured interviews and workshops were employed. A total of
27 interviews were conducted with various airport actors, and five workshops were also held. Each workshop lasted for about four hours, with various representatives from airport actors. Paper 1 reports a full account of this study.

Study II – Case study

In operations management, case study methodology is applied with several methods for different purposes such as exploration, theory building, theory testing or theory extension (Voss et al., 2002; Wacker, 2008). For example Voss (2002) demonstrates case studies as a methodology, and examines the historical or current phenomenon with several sources of evidence. These may include interviews, direct observations, using archives but within a particular context or unit of analysis. In this thesis, a case study methodology is employed in study II for descriptive analysis. This was done in order to uncover the organizational complexity and implications for PM in SoS. Twenty-three interviews (approx. 30-90 minutes) were conducted with representatives from seven different airport organizations. The case study choice relies on the need to explore factors that induce complexity, in order to capture unique behaviors between different actors in collaborators. The Critical Incident Technique (CIT) was supplemented. Subjects were asked to recall any event that was salient in any way to uncover latent dependencies. Paper 2 documents this study and its findings.

Study III – Systematic Literature Review

A Systematic Literature Review (SLR) approach (Cook et al., 1995; Petticrew and Robert, 2006) allows the researcher to focus on the research purpose rather than on the utility of publications as explained in studies made by Ginieis et al. (2012). Traditionally, SLR provides a structured way to summarize various findings with minimum bias. In this thesis, SLR was applied in Study III in order to identify how organizational controls amplify complexity along three process stages of PMS. Specific key works associated with PMM were used as a criterion search of literature output from the Thomson Reuters Web of Science (WOS) and SCOPUS. Particular attention was paid to how interactively organizational controls impact on the process stages of PMS, such as design (Deng et al., 2012; Lohman et al., 2004),
implementation (Bourne et al., 2003; Jääskeläinen and Sillanpää, 2013; Suprapto et al., 2009) and management as adopted by different organizations in different sectors (Bititci et al., 2012; Folan and Browne, 2005; Keong Choong, 2013; Mason-Jones, R. and Towill, 2000; Neely, 1999). This study is reported in Paper 3.

Study IV – Classification and Regression Tree method

Study IV applied two methods: The Classification and Regression Tree method (CART) and the Neural Network method. Study IV is reported in Papers 4 and 5. To begin with, the CART method has been applied to other areas with various studies (Chang, 2012; Harper and Winslett, 2006; Prakash et al., 2012; Zhang and Bonney, 2000). CART is a nonparametric statistical tool that helps segment, rank, and predict membership of items in the classes of a dependent variable. The CART method uses an interpretation of results using a node split to form a classification tree. Each node shows a particular class of indicator and saturation is always reached when terminal node is reached.

The CART algorithm begins with all observations in a single data set to form a tree with a particular split fall. For every split, a particular threshold is reached. The observations are then split into two groups. The split is made on the basis of the independent variable to reduce the total variation in the categorical dependent variable. Following the data after the split, the algorithm then selects the best-fit node for continuous split to reduce the total variation in the categorical dependent variable in order to form a Classification Tree.

To apply the CART method, the sample data was examined with three algorithms in order to select the most suitable data for the calculation. The algorithms tested prior to full calculation were QUEST, CRT, and CHAID. From the pilot results, our results show that of the three algorithms tested on our sample, QUEST had a higher prediction accuracy compared to the rest results. Secondly, QUEST was able to classify measures with a high degree of accuracy and less computational time. In other words, QUEST met all the prerequisites for the data used. As such, the rest of the analysis was performed using QUEST.
As a complement to Study IV, a Neural Network method was also applied for prediction. Neural networks are also referred to as Artificial Neural Networks (ANNs). A neural network is a set of units that are interconnected (Warner and Misra, 1996). These units are also called nodes and are a representation of neurons that attempt to mimic brain function (Rosenblatt, 1962). Neural networks are used to predict events through a process of training the behavior of the network. Prediction serves an important role in air transport because of the unforeseen events that impound the nature of airside services at airports (Liu et al., 2014; Tobaruela et al., 2014). As a machine learning practice, a feed forward artificial neural network model maps sets of input data onto a set of appropriate outputs. This uses a Multilayer Perceptron which consists of multiple layers of nodes in a directed graph, with each layer fully connected to the next one.

In this study, Artificial Neural Networks model was able to develop a prediction model. The model was automatically incorporates relationships between the variables analyzed without explicitly incorporating them into the model (Trujillano et al., 2004). In so doing, the method was able to predict whether the exogenous features between organizations seem to cause delays and hence the effect on time performance during turnaround. This was also achieved by this method to study and train the collaborative measures. Table 3 shows different types of data sets that were collected and used in this thesis. Table 4 shows a summary of results and contributions from each paper. Several types of data were collected in the studies is presented in Table 2.
4.3 Research quality

Table 3 shows a summary of the research quality and different strategies that were considered. As suggested by several scholars (cf. Eisenhart and Howe, 1992; Golafshani, 2003; Morse et al., 2002; Voss et al., 2002), this research utilized five criteria for establishing the quality of research, viz., construct validity, internal validity, external validity, reliability and generalizability. These criteria in relation to the study are discussed next.

Construct validity

According to Yin (2009) and Gibbert et al. (2008), construct validity refers to the extent to which a procedure leads to matching theoretical constructs to reality. To achieve construct validity, three approaches were considered. First, multiple sources of evidence, such as multiple interviews, documents, observations in turnaround operations, operational data, and workshops, were used for selected quotes and facts that significantly affected the theoretical constructs as well as the findings in the cases. Second, operationalization of theoretical constructs was based on previous similar case studies in the extant literature. Third, as much as possible, transparent and documented approaches were used in defining the theoretical variables and clearly linking them to empirical evidence. These steps were carefully followed during data collection and analysis stages.

Internal validity

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According to Yin (2009), internal validity is referred to as logical validity, which deals with the causal relationships between variables and thus separates appropriate causal relationships from counterfeit relationships. To achieve internal validity, different studies tried to replicate the same findings from different approaches and methodologies. For example, Studies I, II and III linked different sources of complexity in PMM from the longitudinal case study, the embedded multiple case study, and the literature review respectively. Similarly, Study IV analyzed the role assignment of actors and its impact on continuous improvement for collaborative PMM. This was achieved from quantitative operational data and the CART method respectively.

**External validity**

External validity (generalizability) is the extent to which research findings explain a phenomenon not only in one setting where it was studied but also within other settings. Since this thesis is mainly based on a case study, statistical generalizations were not possible. Hence, generalizations were achieved by using theories. Thus, for external validity, complexity theory was applied in Studies II and III. Furthermore, Cybernetic theory generalized all findings from different studies in the cover essay. Replication in different settings such as the two cases from two different airports also allowed theoretical generalization. Moreover, different methodological approaches such as simulation for prediction and quantitative data analysis within cases were utilized to enhance the generalizability.

**Reliability**

According to Yin (2009), a study is said to be reliable when the procedure such as data collection or data analysis can be repeated with the same results. The reliability of case studies is difficult to measure considering the fact that cases are enmeshed with the contexts and it is sometimes difficult to replicate the study. Thus, to ensure the reliability of cases, all followed procedures and protocols were carefully recorded and all the interview questions were properly documented and tagged. Ultimately, all the data used built up a database with transparent and robust analysis methods which were also
recorded. With this information, it follows that any other researcher can use the protocols of this thesis to conduct similar studies.

Table 3. Strategies used for research quality

<table>
<thead>
<tr>
<th>Validity type</th>
<th>Strategies</th>
<th>Stage in research</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construct validity</td>
<td>• Multiple sources of evidence, multiple interviews, documents, literature search, observations in turnaround operations, operational data and workshops.</td>
<td>Data collection &amp; Data analysis</td>
</tr>
<tr>
<td></td>
<td>• Operationalization of theoretical constructs using other similar case studies.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Clearly and transparently linking theoretical constructs to empirical evidence.</td>
<td></td>
</tr>
<tr>
<td>Internal validity</td>
<td>• Used robust well known mechanisms for analysis such as: pattern matching. The results were verified by key informants (studies one and two).</td>
<td>Data analysis</td>
</tr>
<tr>
<td></td>
<td>• Used replication of causal links for more than one evidence in cases.</td>
<td></td>
</tr>
<tr>
<td>External validity (Generalizability)</td>
<td>• A replication logic with multiple cases was applied</td>
<td>Research design</td>
</tr>
<tr>
<td></td>
<td>• Analytical generalization- used theory, used CCT as method theory and PMM as domain theory.</td>
<td></td>
</tr>
<tr>
<td>Reliability</td>
<td>• Protocol preparation for data collection, data categorization and data storage.</td>
<td>Data collection</td>
</tr>
<tr>
<td></td>
<td>• Transparent and robust analysis methods for analysis were employed.</td>
<td></td>
</tr>
</tbody>
</table>

Research limitations

Four research limitations were experienced in this research. First, in the studies documented in Paper 1, a project involved a longitudinal study over a period of three years. This process was complemented with semi-structured interviews, workshops, serious game development, and training and mentoring. Although the results were documented correctly, there was a limitation concerning key informants from year to year who changed roles and new ones appeared which could have an impact on the results. Secondly, in Study II, there was a smaller sample size to deal with. For more robust results, this study could have been different with more respondents.
Third, in Study III, the research limitations lie in the way the data was examined. It was not very clear if all the empirical papers discussed social and technical aspects. Although the authors met and agreed on what was technical and what was social, there was still some bias felt in terms of what was actually meant by previous researchers. Fourth, in Study IV, in order to capture system performance, *star value* was set to minimal delay conditions. However, this could be a limitation due to changes that could arise in the calculation of collaborative measures if *star values* were to be set with different values, for example +/- 5-minute delay. Finally, this thesis adopted the use of system theory as a method theory. Although it was applied to explain substantive topics in PMM theory as the domain, not all empirical contingencies were considered which may be a limitation to reflect upon.
5. Summaries of the appended papers

Chapter 5 presents the contribution of each of the five appended papers. In summary, Papers 2 and 3 explore the dimension of organizational complexity. Papers 4 and 5 explore the dimension of continuous improvement. Lastly, the dimension social system is explored through Papers 1 and 3. The chapter ends with Table 4 that shows a summary of results and Vignette 3 explaining post implementation of CDM at Madrid airport.

5.1 Paper 1 – Implementation of collaborative measures

Title: Preparing for Airport Collaborative Decision-Making (A-CDM) implementation: an evaluation and recommendations

Paper 1 reported on an industrial change case that was about the implementation of a collaborative PMS in Airport 1. The study applied an action-based methodology. The main objective was to evaluate what is needed for a collaborative implementation of PMS at an airport. Likewise, the study provided a test bed for the development of a framework for understanding the notion of organizational capacity to manage change with many actors.

A structured inquiry was used with the following dimensions: Operational process, management process, social relations, information and knowledge. These dimensions are part of a system logic methodology called the System Change and Operations Evaluation (SCOPE) which provides an analysis of system performance at different independent levels (McDonald, 2015).

The main findings from this study showed challenges relating to the collaborative implementation of PMS, such as a lack of clear collaborative goals, a change of culture – especially the shift from CDM being an IT project to being a PMS system, a lack of awareness and a lack of collaborative leadership, which causes insufficient system integration. The paper provides a list of recommendations for how such challenges can be addressed. Lastly, Paper 1 explores different dimensions at implementation stage as a process stage along the PMS lifecycle. The study tested the overall use of the SCOPE methodology and found it to have a high face validity and stronger acceptance.
for its approach, especially in inter-organizational PMS. The key contribution of this paper is that it shows how collaborative measures are implemented and challenges are confronted.

5.2 Paper 2 – Factors that induce complexity

Sources of Complexity within a System of Systems: Implications for Performance Management

To understand the dynamics of collaboration and roles among actors, Paper 2 adopted an exploratory case study using 23 interviews among airport actors from different organizations collaborating on a single PMS at a major European airport. In addition, participant observations over eight months were also conducted. The main purpose was to identify complexity factors in the turnaround process when viewed as a system of system. To understand the implications for PMM, Paper 2 describes airport services’ organization and operations in terms of the service types they provide. Ultimately, Paper 2 also identifies contingencies contributing to the complexity of in-airport services with implications for collaborative measures. Since airport actors are involved in highly integrated and complex operations, the paper gave a background on how different organizations interact in daily operations using a shared PMS. The dimensions that were explored were the interactions and dependencies among different service providers and clients in the turnaround process. The main findings from this study revealed that several factors create complexity in the turnaround SoS, which threaten PMM in a complex multi-stakeholder organization. As a result, three implications for PMM are identified as: (i) organizational complexity, (ii) continuous improvement, and (iii) performance management (PM) as a social system.
5.3 Paper 3 – Performance Measurement Complexity

Performance Measurement Systems – Art and Science: A Perspective from Complexity Theory

Paper 3 explores the apparent nature of complexity as part of PMS, in contrast to how complexity in PMM literature has been postulated to be a result of the wider external environment. The paper argues that organizations face internal complexity when adopting a PMS. Underestimating this complexity may increase uncountable costs to organizations. The study applies a complexity-theory perspective to internal aspects, and explores how organizational controls amplify complexity at the three core process stages of a PMS lifecycle, i.e., design, implementation and operations. A wide variety of PMM literature was considered using a systematic literature review with a sample of 58 papers, which are appraised in depth. The results demonstrated that social and technical controls impact on PMS process stages and contribute to complexity in two ways: Firstly, users lack clear and concise administration between the balance of objectivity and subjectivity in PMM at each process stage. Secondly, the range of elements interacting in the system are difficult to manage with their inter-relationships across the three process stages of the PMS lifecycle. As such, the interaction of organizational controls in the system is emergent, unintended, unpredictable, and ambiguous in term of what to measure and lacks synchronization. The key aim of this paper is to study a specific aspect of performance measurement, which is its complexity. The study’s main conclusion is that organizational controls cause Performance Measurement Complexity (PMC), which has six sources, i.e., analytical, methodological, technological, role, procedural and task complexity.
5.4 Paper 4 – Managing through collaborative measures

Managing turnaround performance through Collaborative Decision-Making

Paper 4 explores the role of collaborative measures for continuous improvement and shows the lack of ownership rights for collaborative measures. Paper 4 explores the management of airport performance in the turnaround process (TAP) that includes ground handlers, airlines, the airport management, and air navigation service providers. Since such a network performs in ignorance because of a lack of central decision-making authority, a special set of variables called star values was introduced as an objective decision-making authority to examine the role of collaborative measures.

The paper examines the role of using collaborative measures as a feedback mechanism with actors in collaboration. This is important as it enables the alignment of output from different PMS users to push for changes in the system (van Bakel et al., 2015). Secondly, to measure overall performance collaboratively, Paper 4 contributes to overall improvements in constructing a re-balanced network by answering the following research question: How is the turnaround managed within Collaborative Decision-Making?

The findings indicated that collaborative measures provides insights for continuous improvement such as: if the network is an extendable system, a profitable system, or a self-learning system. However, findings revealed that collaborative measures still lack ownership rights. The key contribution of this paper to the thesis was that it goes into greater depth on how collaborative measures would enhance the effectiveness of operations if feedback mechanisms were provided. Indeed, such a network could be able to manage with collaborative measures. In particular, the paper shows variations in predictions and how such a network performs in ignorance.
5.5 Paper 5 – Predicting the use of collaborative measures

Prediction of Airport Infrastructure Performance with Collaborative Measures: Studies from Barajas Airport (working paper)

Paper 5 explores the role of prediction in managing with collaborative measures. The purpose of Paper 5 was to identify the role of exogenous factors and their impact on causing delays by hindering on-time performance. In order to achieve this, features or elements that are indicative of causing delays or slowing down airport operations in the turnaround such as gate location, runways, type of aircraft and type of airline company were analyzed using a predictive model. Moreover, in addition to the KPI system defined in the airport PMS, exogenous factors with a high degree of relevance were identified as type of aircraft, type of runway, company, and gate number in that order.

The findings from this study indicate that specific elements that are collaboratively shared seem to affect the quality of performance measurement characteristics and may not be easily discernible as being exclusive from each organization. Furthermore, it appears that collaborative networks are faced with a challenge of resource integration, as there are contextual factors that affect performance measurement regardless of the quality of collaboration. However, the predictive model provided a method to identify the most important exogenous factors to avoid future risks. General findings from Paper 5 contribute to this thesis on the roles of exogenous factors that may affect network performance regardless of the quality of collaboration, trust and information sharing among actors. As such, feedback mechanisms may not be rigorous enough to capture full system performance, as exogenous factors also affect the collaboration structure.
Table 4. Paper Summary

<table>
<thead>
<tr>
<th>Paper</th>
<th>Main Data source</th>
<th>Purpose</th>
<th>Method</th>
<th>Findings</th>
<th>Answer to MRQ</th>
<th>Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>27 interviews, five workshops</td>
<td>Studying implementation of Collaborative Decision-Making</td>
<td>Longitudinal action-based research</td>
<td>Challenges faced in implementing collaborative measures and recommendations</td>
<td>How collaborative measures are implemented and challenges encountered</td>
<td>How challenges during the implementation of collaborative PMS can be overcome</td>
</tr>
<tr>
<td>2</td>
<td>23 interviews Three workshops</td>
<td>To identify complexity factors in airport turnaround</td>
<td>Case study</td>
<td>System analysis and Factors that induce complexity are identified</td>
<td>Shows complexity factors and implications for the process of inter-organizational PM</td>
<td>Factors that induce complexity as a result of collaborative measures</td>
</tr>
<tr>
<td>3</td>
<td>Thomson Reuters and Scopus databases</td>
<td>To explore how technical and Social control amplify complexity at PMS process stages</td>
<td>Systematic literature review (SLR)</td>
<td>Typologies of complexity in PMM</td>
<td>Shows sources of complexity along PMS process stages through social and technical controls</td>
<td>How complexity emerges along three process stages of PMS and as a result of internal environment</td>
</tr>
<tr>
<td>4</td>
<td>6,500 observations of operational data</td>
<td>To explore turnaround performance as a resultant of collaborative measures</td>
<td>Classification and Regression Tree method</td>
<td>Shows characteristics of collaborative measures and use</td>
<td>Shows the effect of lack of interpretive rights and how it affects continuous improvement</td>
<td>Shows the process of continuous improvement with collaborative measures through modelling</td>
</tr>
<tr>
<td>5</td>
<td>Taxi time indicators from airport operations</td>
<td>To predict the effect of exogenous factors that affect the performance of collaborative measures</td>
<td>Artificial Neural Network (ANN)</td>
<td>Identifies factors other than actors that affect the performance of collaborative measures</td>
<td>Shows that collaborative performance is also affected by exogenous factors</td>
<td>Prediction enables collaborative measures to predict future risk</td>
</tr>
</tbody>
</table>
Post-implementation of collaborative measures at Madrid–Barajas Airport.

How do we measure success collaboratively?

Vignette 3

In late 2014, Madrid–Barajas Airport was certified by regulators as having implemented a shared PMS. It was the 12th airport in Europe to adopt CDM. However, after full implementation, actors working to adjust their operations started to raise questions regarding how to measure performance for success. For some actors, operations did not change at all. Most flights and turnaround processes were not affected. They would act the same way, and they would follow the same procedures. For some it meant increased workload, and for others it meant allowing losses due to the operational requirements of the system. For other actors, new measures needed to be revised. The diversity of the strategic objectives and interests from each airport actor also posed a challenge in relation to who will establish the measures in order not to affect the operations of others. This triggered a discussion on the use of collaborative measures and what future indicators will mean to the network. What was to be measured and how should it be monitored? On a monthly or an hourly basis? During peak hours or advance conditions? Actors then realized that some benefit more at the expense of others and some could not adjust internal specific KPIs which could affect the operations of others. To this day, airport actors still operate with delays in all parts of the turnaround. The main challenge is that such a process is being conducted in a “command and control style”. It appears that actors do not see visible benefits and the network is not balanced, hence the process of continuous improvements is not fully documented to realize the benefits.
6. Discussion

This chapter answers three sub-questions and discusses the results analytically by applying CCT theory under the three dimensions. There are three main findings: interactive complexity as systemic complexity, the realization that performance in ignorance exists, and factors that affect the social system in an inter-organizational setting. The findings from each research question are discussed separately.

6.1 Research questions answered

RQ1.1: What are the sources of inter-organizational complexity?

The first question explored the first dimension in inter-organizational PM which is organizational complexity. Results from Paper 2 show factors that induce complexity, including the existence of informal roles between actors, and critical incidents and non-linear interdependencies between work processes. Other sources of complexity were the number of actors involved, the size of entire network, and the quality of information needed to be shared among actors. These factors were shown to induce complexity in the network. From Paper 3, findings indicate that PMS exists with an intrinsic complexity, which is termed Performance Measurement Complexity (PMC). Six sources of PMC were identified as analytical, methodological, technological, role, procedural, and task complexities.

This finding revealed that actors operate with several sources of complexity in their internal organizations. It follows that if actors were to collaborate with distinct roles, organizational complexity in the network is amplified at the system level, meaning that actors who manage using collaborative performance measures operate with several sources of internal complexity, which aggregates to the system level. In the context of this thesis, system complexity that results from each actor internally is termed interactive complexity, and thus identification and regulation of iterative complexity is one of the roles between collaborating actors, which in this case is the process actor and sensor actor. According to cybernetics, the process actor is the system itself. The behavior of the system is monitored through control
variables such as information, knowledge, and trust. The actor’s role in this case is to monitor and identify sources of complexity within the system. For the sensor actor, which is for error detection, its role is to interpret the behavior. For cause and effect to apply, a tentative proposition from cybernetics control theory is that the sensor actor monitors for error detection while the process actor interprets the errors.

**RQ1.2: How do actors collaborate while continuously improving?**

The second sub research question explored the second dimension which is continuous improvement. This deals with organizational performance that controls best practices. Findings suggest that continuous improvement is hindered, causing collaborative PMS to be static and less responsive. This was demonstrated in Papers 1, in which actors lacked collaborative strategies, and because of their differing interests, they lacked interpretive rights to set measures. Such a network “performs in ignorance.” These findings were tested in Papers 4 and 5 to examine the usefulness of collaborative measures. In Paper 4, by introducing the predictor variable called star value, it captured the dynamic nature of collaborative PMS. The predicted measures showed how airports can use collaborative measures to assess on-time performance resulting from activities during turnaround. The method in Paper 4 also predicted measures that actors can use to align strategies so a collaborative PMS benefits all parties involved. By considering a predictive model, Paper 5 shows which airport resources are critical to causing delays. Results from Papers 4 and 5 reveal that collaborative measures can be used by managers as a feedback mechanism to push for enhanced decision-making. However, actors still lack a premise with which collaborative measures can be adjusted to continuous improvement.

Strategic control systems, such as those discussed by Ferreira and Otley (2009) offer possibilities for structuring decision-making to continuous improvement. Regarding collaborative decision-making, these models are limited since they do not cater to all demands of the network. Inter-organizational PM lacks interpretive rights to capture full system effectiveness. It follows that managing collaboratively for continuous improvement should be extended to acquire cybernetic roles and therefore
be more reflective of a rebalanced network. The tentative proposition, according to the cybernetic framework, would be actuator for its roles as manipulator and interpreter of the system.

**RQ1.3: How do social aspects affect inter-organizational performance?**

As a social-technical process, turnaround directs attention to sequencing activities that are highly technical, but with people as agents in the system. Their know-how, actions, and interactions collectively produce the social system. When it comes to inter-organizational PM, social systems comprise constant reproduction of social interactions. Results from Papers 1 and 3 indicate that social logic affects management of collaborative measures in two ways. First, Paper 1 explores social logic by using a conceptual architecture for system performance, as developed by McDonald (2015), which explored two dimensions: trust and team structure. Inter-organizational PM under this dimension is largely affected since partners lack trust in the shared PMS, rather than trust between stakeholders.

There is an imbalance in team structures since steering groups from disparate groups have different logic maps from other stakeholders in lower positions. In contrast to Paper 3, results show that users lack clear and concise administration in terms of how to balance objectivity and subjectivity when applying social and technical controls. According to Paper 1, the team map shows social logic being affected by trust and team structure, whereas in Paper 3, the model that typifies social and technical shows sources of social complexity. This means social systems interfere with collaborative measures in a broader way, and several views exist. Other social aspects reported in the network, such as poor communication, sense of urgency, and lack of collaborative leadership, show the role of social aspects when creating a guiding coalition to institutionalize new approaches for inter-organizational PM. For managers of collaborative measures to go beyond these social tensions, the cybernetic role as the controller actor would be included in the network. In cybernetics thinking, the controller actor executes commands between social and technical network processes, thereby creating a balance for all actors because the task of command not only is determined as a
correction function, but also considers actors’ interests through the sensor element.

6.2 Reconnecting to the Main Research Question

Having discussed results in relation to the sub-questions, this section explores how the sub-questions relate to the main research question.

**MRQ: How do actors manage operations through inter-organizational performance measures?**

Actors who manage using collaborative PMS operate with a range of interacting elements and processes that create redundancies in operational measurements. This results in technical complexity that is systemic. This complexity type, termed interactive complexity, influences the process of maintaining a collaborative PMS. Actors operate with operations that are broad, covering a dependency network, important measures are dynamic, multifaceted, multileveled, and multilateral in such settings. Based on findings from Study IV, a collaborative PMS lacks interpretive rights to set new measures, making it static.

Findings from Papers 1 and 3 reveal several social aspects that affect actors who manage using collaborative measures. First is a lack of clear and concise administration between the balance of objectivity and subjectivity at different PMS stages. Second, Paper 1 suggests a lack of trust, not between actors themselves, but in the shared PMS. In such settings, actors operate with disparate professional knowledge. Stakeholders on operational level do not have similar knowledge to those in senior management positions. Airport actors also face issues around information sharing, leading to various contradictory factors and incongruences, in terms of what to measure and how.

Contributing to the main research question regarding how actors manage through a collaborative PMS, the method theory suggests that actors adopt a cybernetic framework, which is summarized in Figure 6. The framework shows a proposal for such settings, emphasizing the misalignment between
inputs and outputs, and distributions of roles for the need of a feedback loop. Based on the discussion in Section 6.1, the cybernetic framework recognizes that there exist several PM dimensions that can be adapted and explored for inter-organizational PM. The proposed framework uses the three PM dimensions to illustrate how it should function. The proposed framework functions with the recognition of three layers: the functionality, interoperability, and inter-performance management layers. These layers result in collaborative decision-making. Role distribution in these three layers is illustrated by the four cybernetic roles that influence each other to produce a cause and effect. through a Reflective Performance Measurement System.

There are three main considerations that the framework puts forward. First it considers the importance of the cause and effect as described by CCT theory. Second, the importance of RPMS with general conditions stated in Section 7.2. Third, it puts forward the importance of cybernetic role distribution among actors.
7. Conclusion

This chapter concludes by discussing the usefulness of adopting CCT as a method theory, and presents implications both to theory and practice, with anticipation of future research.

7.1 Cybernetic roles: Focus for inter-organizational PM

Effective PM practices remain sufficiently dynamic and responsive, whether in a single business or in a network (Adler, 2011; Bourne et al., 2000; Kandjani and Bernus, 2012). By investigating three PM dimensions, discussed in Chapter 3, this thesis demonstrates a fundamental challenge when managing using collaborative measures since it creates a feedback dilemma between collaborative measures and strategies, which often results in an inconsistent PMS. Results indicate that challenges encountered while managing with collaborative measures can be controlled and managed using cybernetic thinking (Kandjani and Bernus, 2012; Schwaninger, 2015). The discussion calls for a new focus on PMM that is emerging from organizational cybernetics. Thus, as a method theory, CCT offers a solution for actors, seen through role distribution in network as sensor, commander, actuator, and process roles. The roles are taken as inter-organizational PMM entities, and consequently, roles among collaborating actors are applied to provide critical, useful, and required functions. This conclusion is based on the following assumption. Cybernetic theory is a scientific study that is interdisciplinary and explains any behavior directed toward a goal. Cybernetic theory, discussed in Chapter 2, explains the management needed for PM as an inter-organizational measurement system (Christopher, 2011; Mol and Beeres, 2005). It does so by managing strategies such as the planning-monitoring-controlling cycle with collaborative measures between actors. Feedback mechanisms of performance measurement in networks comprise a system that initiates a central decision-making authority if actors adopt cybernetic control roles correctly.

Figure 7 presents the usefulness of adopting CCT theory as a method theory. The role of cybernetics in inter-performance measurement allows four types of information to be collected for the system: (1) system information
with a feedback mechanism, (2) information that allows the feedback mechanism to manipulate system measures though controllers, (3) information that allows feed-forward to link with control loops, and (4) information concerning external factors that allow continuous improvement for SoS, and thereby mitigate complexities and control social aspects that affect PM. The four cybernetic roles account for every action in the system, and hence the notion of chain and cause effect is realized.

![Cybernetics Control Theory](image)

**Figure 7: Illustration of usefulness of cybernetics control theory to PMM**

### 7.2 Implication for theory

Findings from this investigation contribute to the theory of collaborative PM in three ways. First, the findings extend a theoretical model for continuous improvement to a reflective PMS. Second, the findings advance our understanding of the evolution of inter-organizational complexity as a result of new types of complexities that emerge internally, and third, the findings show how the social system is affected by trust and team structures. The following section discusses the theoretical contributions in detail. Table 5 shows the synthesis of results and how each dimension was answered.
**Table 5. Synthesis of the results**

<table>
<thead>
<tr>
<th>PM dimensions</th>
<th>RQ1.1</th>
<th>RQ1.2</th>
<th>RQ1.3</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organizational</td>
<td>Paper 2</td>
<td>Paper 3</td>
<td></td>
<td>Inter-organizational PM is challenged with the misalignment between inputs and outputs, which impedes collaborative decision-making. For such a system to stay dynamic and responsive, actors should adapt to unique cybernetic roles to correct the misalignment through a chain and cause effect.</td>
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<td>complexity</td>
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<td>Social system</td>
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**Organizational complexity**

The primary theoretical contribution made under this dimension is the understanding of how internal complexity propagates and aggregates as systematic complexity, including its evolution. This new type of complexity is termed interactive complexity in this thesis. Extant research on PMM primarily documents complexity based on the idea that it is a result of external environments (Grobman, 2005; Harkness and Bourne, 2015; Morel and Ramanujam, 1999). This research agrees with the view that external/environmental complexities exist, but also argues that internal complexities are paramount, and have been ignored in the literature. Results from Paper 3 show sources of new types of internal complexity.

This study defines interactive complexity as a contest between internal complexities of each collaborative organization, which aggregate and are systemic. The theory contribution is that it extends the discussion of Folan and Browne (2005) on the evolution of complexity in inter- and intra-systems. The evolution that appears in the literature is that as PM practices matures and expands, intra-organizational PM achieves lower complexity and reaches its limit since it is easier to manage. However, for inter-organizational PM, complexity keeps increasing since the system is open and dynamic.

With identification of internal complexity, evidenced in Paper 3, it follows that the evolution of inter-organizational PM is amplified for two reasons. First is interactive complexity, which is systemic, and second is the
incompatibility of frameworks between the intra and inter because extended PM literature assumes similarity between inter and intra, and frameworks are not designed to manage diversity of interactive complexity, hence the incompatibility. Since PMM is too focused on intra-complexity as an external source, interactive complexity is underestimated. Figure 8 shows how interactive complexity contributes to the previously known evolution of inter-organizational complexity.

![Figure 8: The evolution of inter-organizational PM as a result of interactive complexity (expanded from Folan and Browne, 2005)](image)

**Continuous improvement**

Theoretical influence under this dimension is seen in two ways. First is extending the theoretical model to continuous improvement, and second is realizing that a broader way of assessing measures systematically is needed in PMM literature. The theory contribution is discussed by the need for an additional performance system, which is termed Reflective Performance Measurement System (RPMS), analyzed and interpreted through the theoretical model for continuous improvement by Pinheiro De Lima et al. (2013) and influenced by Folan and Browne (2005).

Regarding inter-organizational PM, the model is limited since both double and single loops are limited. Within the context of this thesis, continuous
improvement for collaborative measures is limited for the following reasons. First, results from Paper 4 show that collaborating actors are unable to discern optimum continuous improvements. The paper applied a new component called star values, which was adapted to fill this gap as a decisive measure to examine the operational capabilities of collaborative measures to facilitate continuous improvement. Without star values, such networks perform in ignorance. Second, single and double loops do not allow all actors’ views and interests, and the system is therefore imbalanced and cannot keep the system dynamic and responsive.

If the system is to learn, adapt, and produce a predictive element for future risks, these roles should be distributed throughout the system. The theoretical model from Pinheiro De Lima et al. (2013) is then functional for all actors. Figure 9 shows the operational strategic management system with the extension of the needed reflective PMS

![Figure 9: Reflective performance measurement system for continuous improvement adapted for the Operational Strategic Management System by Pinheiro De Lima et al. (2013)](image)

As an implication for theory, a new PMS called reflective performance measurement is proposed, extending the model to set continuous improvement between actors. Given the nature of SoS, a RPMS should include an element of meta–reflectiveness, questioning how single and double loops measure network operations. This means that the first loop in Figure 7 considers efficiency, and the second loop – effectiveness. For inter-
organizational, it considers the appropriateness of the selected PM in the other two loops. Conditions are proposed for RPMS when facilitating inter-organizational continuous improvement. First, there are general conditions that apply universally, but the system recognizes unique conditions that are more specific. Figure 9 shows the additional system, termed a reflective performance measurement system, which extends the theoretical model.

To summarize, general conditions for a reflective PMS should:

- Be centralized, with a balanced reporting history from all actors;
- Possess a balanced information infrastructure dispersed to all actors, and reassure partners of the confidentiality of data;
- Emphasize the balance between social and technical controls;
- Enable stakeholders to trust data and have balanced knowledge about shared PMS;
- Validate business cases;
- Be reflective to accommodate regulative demands from policymakers.

With these conditions, RPMS allows the network to remain dynamic but balanced. The system is then improved, and organizational aspects of the system are enhanced as continuous improvement is enacted. The implication for theory is that when considering the theoretical model, which discusses feedback loops in Figure 7, there is an importance in terms of the broader way of assessing measures that is systematic, which PM literature requires.

**Social system**

Under the third dimension, extant research suggests that organizations are social systems, and people run their operations. However, the literature has not paid much attention, and little documentation exists, on how PM exists as a social system. In line with Papers 1 and 3, findings under this dimension operationalize PM as a social system and contribute to theory in the following ways. First, the study adopts the system performance conceptual architecture developed by McDonald (2015) (see Figure 2 in Paper 3), which shows social logic being affected by trust and team structure. Second, in Paper 3, internal
complexity was realized leading to a new type of complexity called Performance Measurement Complexity. The implication is that as opposed to previous notions of the social-technical approach, these social complexity factors are vital to inter-organizational PM.

7.3 Implication for practice

Managing PM in a single organization is difficult, and managing inter-organizational PM, as this thesis shows, is not only difficult, but nearly impossible (Folan and Browne, 2005). Managers will now realize that contemporary business contexts are characterized by alliances among businesses, thus establishing strategic alliances (Semlinger, 2008; van Wijk et al., 2012). The reason for such trends is embedded in the nature of firms; they are involved in various networks and inter-business relationships to co-create and appropriate value (Johansson, 2012). There are important frameworks managers can apply when managing using collaborative measures. In Paper 4, a model that evaluates collaborative measures is proposed and tested using real flight data during turnarounds. The model considers airport operators, aircraft operators, ground handlers, and air navigation service providers as airport partners, and their activities as inputs to the system. As for outputs, the model considers efficiency, environment, capacity, and safety. With this model, managers can apply star values to evaluate system performance.

A model that typifies social and technical controls is proposed in Paper 3. Managers can map processes with this model, and examine which stages require high/low technical or social controls. A model in Paper 5 is also proposed and tested that predicts critical use of airport resources. Actors operating in airports and similar settings can apply the model to allow proper use of shared resources. Findings made from testing the three PM dimensions reinforce practical interactions and use of organizational controls, such as technical and social, to cause complexity. This measurement is emergent, unintended, unpredictable, and ambiguous in terms of what to measure and how to manage it. Results suggest that users’ responses to the external environment cause internal Performance Measurement Complexity (PMC), meaning that stakeholders have two tasks: managing their unique internal
complexity, which propagates through six sources as analytical, methodological, technological, role, procedural, and tasks, and collaborating on managing interactive complexity at the system level, which has a huge influence on managing inter-organizational PM. Since collaborative measures are a critical factor when developing strategic alliances, team leaders should realize the importance of controlling and managing internal complexity, as opposed to traditionally focusing on external complexity. This is illustrated by Deloitte, a multinational, professional service provider. While reinventing its PMS system, Deloitte found that approximately 2 million hours each year were spent on formalities of performance management (Buckingham and Goodall 2015). If Deloitte were to collaborate with other organizations with similar levels of complexity, the focus had to be on shared complexity that emerges, which is termed interactive complexity in this thesis. As a contribution to practice, team leaders should realize the importance of including a reflective element for the entire system, rather than ad-hoc adaptations to select parts of the system.

This thesis also shows that organizations are naturally social systems. The implication for practice is that managers would pay attention to the people component by controlling use of technical and social controls, and balancing where needed. Managers would understand that organizations have different social logical maps on what to measure and how. The implication is that understanding use of collaborative leadership, communication, and dialogue (Yates and Orlikowski, 1992) delimits the imbalance of know-how and strategic mismatch that exists with actor diversity. The influence for practice is that emphasizing open information platforms narrows the strategic consensus, which presently varies considerably between steering managers and operators (Edh Mirzaei et al., 2016).

An implication for managers operating with PM that transcends organizational borders is to allow cybernetic roles for the chain-cause effect. The network understands collaborators if they are contenders, partners, and integrators, balancing their views and interests. Such definitions have implications for technological developments of future PM tools. PM tool developers and providers should advance them to provide unique constructs for actors operating with collaborative measures by providing information-
sharing flexibility and network feedback alignment that is balanced for all actors, while maintaining trust and ethics of partnering and thus contributing to reflective PMS for interoperability and functionality.

Last is decentralizing by delegation of decision rights. Managers would realize that critical to attaining a central decision-making authority is delegating jointly by concentrating on all actors, without excluding others. Since this thesis explores a highly regulated setting, there are important implications for policy. Regulations on industrial collaboration and its governance are important to PM and the economy. From this thesis’ findings, regulators know that systematic measuring is important, and new regulations should be designed to allow collaborating businesses to involve cybernetic thinking, especially during contract formations and memoranda of association. Managers would then face the challenge of feedback with ease and equivocally, especially when dealing with trust and removing extra intentions such as monopolistic tendencies, estranger behaviors, syncretic rent-seeking behaviors, and profit-seeking.

7.4 Avenues for further research

Results from this thesis highlight several avenues of inquiry. Most importantly, this study takes a perspective in PMM literature based on the philosophy of managing through measures. However, new perspectives in the literature have repeatedly emerged that suggest that managing through measures is outdated, and more freedom motivates collaboration. Therefore, future research should use this perspective to understand whether inter-organizational PM can be managed with less or no measurement.

Three immediate avenues for further research are suggested by this thesis. First, only three dimensions are explored in this thesis. To explore further what sustains a collaborative PMS, future studies should exploit additional dimensions from PMM literature. Examples include organizational learning, actors’ satisfaction with PMS design, and productivity through team tasks (i.e., the amount of resources used to produce a unit of work). Future research should extend to contexts in which conditions vary, such as business size, degree of technical and social controls, and variety of KPIs.
Second, sustainability of PMS design in collaborative networks (Pekkola and Ukko, 2016) should be examined. Future research should examine operational reward systems within stakeholders if they sustain the functionality and commitment of stakeholders to network demands.

Third, the methods proposed and applied for investigation in this study can be complemented and broadened. Future research should enhance methodology selection and rigor. An example is new methods to capture what makes PM a social system, such as ethnography. For generalization, future research should be conducted in other industries to advance or challenge the findings in this thesis. PMM researchers should explore complexity in emergency health care, where many actors collaborate on the inflow of severe inpatient cases. Other contexts worth investigating are railway networks, complexities in operations that exist between army units and military logistics during frontline battles, and the operation management stage of plays and theatre. Operational complexity and tensions that exist in these contexts might reveal results in terms of how a shared PMS can be managed.

Finally, in study, a cybernetic framework for actors managing through collaborative PMS has been proposed. Future work could validate the degree of its application for it to be successful.

7.5 Reflections and final remarks

Having conducted this study as an inside researcher at Madrid airport, and having interacted with several airport actors, I offer final remarks regarding turnaround operations.

First, diverse interactions and relationships with specific contingencies were challenging to operationalize. Since airports are performance-based organizations and due to the nature of operations, focusing on inter-organizational PM appears to be a better choice because it drives important implications. However, it was challenging to capture all contingencies that existed from the empirics of this study. To remedy this challenge, it is essential to conduct an extended pre-study to discern several factors that affect collaborations.
Second and related to the observation of the diversity of actors in this context, as a researcher, I observed that other operations management processes where collaboration is key, such as, collaborative manufacturing settings (Winroth, 2004), automotive and collaborative supply chains, all focused on lean thinking and had similar tac times, similar quality levels, and nearly the same structure of operations. In contrast to such similarities, operations management at airports involves a great deal of diversity in terms of what actors focus on, their views, and their interests. For example, airport managers focus on how many additional slots can be sold, airlines focus on how many rotations can be made with less turnaround time, ground handling companies on how many aircraft can be served with the same staff, and air traffic departments on runway throughput. On another level, regulators focus on the environment and capacity enhancements, and it is difficult finding common indicators for all stakeholders.

Third, after examining PMM literature, I agree with Marr and Schiuma (2003), who acknowledge that the present literature is diverse in terms of issues of collaboration and inter-organizational PM. A more cohesive body of frameworks is needed. A recent special issue on performance measurement and a management conference (Editorial, 2016) confirm that despite abundant research in several areas, a meta theory on PMM has not emerged.

Fourth, in addition to cybernetic roles, the emergence of service 4.0 is worth exploring further. The idea of incorporating automated systems such as Cyber-Physical Production Systems (CPPS) in increasingly feasible (Frazzon et al., 2013) because cyber-physical systems focus on connectivity and objectivity. The cryptal-physical perspective (Angelis and Okwir, 2017) has a physical and digital world. This incorporates an individual level to the social-technical process, making the system highly connected and virtual.

Finally, is the challenge of what it means to collaborate in such environments. According to strategic literature, various researchers emphasize varying rationales behind the decision of firms to involve in collaborative relationships, which may include, Common interest (Dyer and Singh, 1998), collective competitive threat and private profits (Luo, 2007). Mobilization and leverage of resources (Bengtsson and Kock, 2000; Peng and Bourne, 2009; Sawler, 2005). Technological uncertainty and change
While these and more reasons prompts firms to collaborate, PMM literature recognizes that collaborative PMS should be typically dynamic and balanced to meet a variety of managerial characteristics for all actors in collaboration (Bititci et al., 2012; Melnyk et al., 2014; Nudurupati et al., 2015; Pekkola and Ukko, 2016). However, Busi and Bititci, (2006) critically states that there is lack of understanding what it means to collaborate for the development of PMS. A lack of understanding of what collaboration means and what it implies on the development of appropriate PMS is one of the threats facing collaborative PM. My experience from this research, it appears that collaboration for inter-organizational PM will mean to align all processes and functions, teams and individuals, business units and value streams both horizontally and vertically with each actor influencing the other. This will demand actors to refrain from their interests for the network and share more information.

This thesis began by observing that although PMM literature continues to discuss the design of collaborative PMS, there is still a central challenge of feedback mechanisms resulting from inter-organizational PM that has long been ignored. Three PM conceptualizations were explored, with the purpose of investigating how they affect management of collaborative measures. To achieve this, this thesis explores how collaborative PMS is managed with disparate actors in airport operations. The study was based on different methods. Longitudinal action research in Study I explores the challenges of implementing a shared PMS. Study II employs a case study to explore sources of complexity, and understand the context. Study III examines the literature using the SLR method, and the Classification and Regression Tree (CART) and Artificial Neural Network methods are applied in Study IV.

This study uses CCT as a lens to explain and advance the challenges of feedback in inter-organizational PM. Cybernetic Control Theory explains how such loops can be corrected as an alternative for actors to overcome this challenge. If the idea is accepted, the content of feedback discussed in this thesis is also characterized by having fast responses, especially during decision-making between parties, such as collective interpretive rights to set measures, collective rights to own measures, and collective rights to inform
management for continuous improvement while controlling organizational complexity. Collaborative measures are then expanded for many functions to move the network, both strategically and operationally.

This thesis analytically argues that inter-organizational PM can be achieved through the chain and cause effect, which occurs when collaborating actors share roles and influence each other to mimic feedback in cybernetics. This thesis also suggests that collaborating actors do not collaborate particularly, but influence each other for realignment and rebalancing the network. The significance to collaboration through collaborative measures is a process of influence from one actor to another. This thesis points out that collaborative PMS is set to shift from being static to dynamic, and therefore not just a performance management system, but a collaborative system.

This study creates a foundation for further understanding of inter-organizational PM. It encourages several research directions and enhances present knowledge of PMM, and inter-organizational PM more specifically.
8. References


