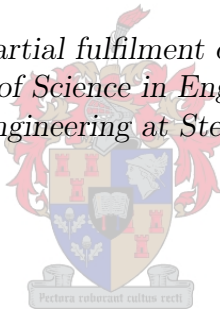


Investigating Social Network Analysis as a Method to Map
Primary Constraints in Physical Asset Management Strategy
Execution

by

Jan-Hendrik Baum

*Thesis presented in partial fulfilment of the requirements for
the degree of Master of Science in Engineering Management
in the Faculty of Engineering at Stellenbosch University*



Department of Industrial Engineering
Stellenbosch University
Private Bag X1, 7602 Matieland, South Africa

Supervisors:

Prof. P.J. Vlok Prof. C.S.L. Schutte

December 2012

Declaration

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Date: 2012/09/03

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Abstract

Investigating Social Network Analysis as a Method to Map Primary Constraints in Physical Asset Management Strategy Execution

J. Baum

*Department of Industrial Engineering
Stellenbosch University
Private Bag X1, 7602 Matieland, South Africa*

Thesis: MScEng (EngMan)

December 2012

The successful execution of the Physical Asset Management Strategy (PAMS) is an important value driver for organisations, whose core business is highly dependent on the service delivery of physical assets. However, contemporary research demonstrates that scheduled targets are often not met and the means to detect the constraints that can undermine the strategy execution efforts are deficient. The purpose of this thesis is to investigate Social Network Analysis (SNA) as a method to map primary constraints in Physical Asset Management Strategy Execution (PAMSE). A comprehensive literature review addresses the domains of Physical Asset Management (PAM) and SNA. The review of the literature is supported by interviews with practitioners in the field of PAM. Consequently, the challenges experienced in PAM are contextualised along with the capabilities of SNA and the most important constraints in PAMSE are identified. As an interim result, the study found that dysfunctional information flow and poor decision making are the primary constraints that could hinder the execution of a PAMS. As a consequence thereof, a SNA application methodology was developed in order to scrutinise these areas of concern. The methodology was applied at two research sites in the South African mining industry. Network data for the study was collected by surveys conducted in June and July 2012. The case studies demonstrate that a SNA application in PAM requires a number of prerequisites that are crucial to its success. Nevertheless, a successful SNA application may yield valuable results identifying the problems encountered in PAMSE. Most importantly, the SNA highlights overloaded key employees, collaborative breakdowns and excessive intradepartmental collaboration that have the

potential to hinder the PAMSE process. The results were validated by means of dialogue with the individuals involved in the study. This study found that SNA can be used as a method to map the primary constraints experienced by PAMSE. It also emphasises that there are important prerequisites that have to be established for SNA to be successful. Future research could be carried out based on the results of this thesis, in order to design improvement plans for the studied research site and possibly conduct a second SNA to investigate whether the constraints, identified in the study, had been resolved.

Uittreksel

'n Studie van Sosialetwerkanalise as 'n Metode om Primêre Beperkings van Fisiese Batebestuurstrategie Uitvoering uit te lê

("Investigating Social Network Analysis as a Method to Map Primary Constraints in Physical Asset Management Strategy Execution")

J. Baum

Departement Bedryfsingenieurswese

Universiteit van Stellenbosch

Privaatsak X1, 7602 Matieland, Suid Afrika

Tesis: MScIng (IngBes)

Desember 2012

Die suksesvolle uitvoering van die Fisiese Batebestuurstrategie is 'n belangrike genereerder van waarde vir organisasies waar die kernbesigheid tot 'n groot mate afhanklik is van die dienslewering van fisiese bates. Hedendaagse navorsing wys egter dat geskeduleerde mylpale meestal nie bereik word nie en dat die metodes wat gebruik word om vas te stel watter beperkings die strategie-uitvoering ondermyn, ontoereikend is. Die doel van hierdie tesis is om die aanwending van Sosiale Netwerkanalise as 'n metode te ondersoek, om die primêre beperkings ten opsigte van die uitvoering van Fisiese Batebestuurstrategie te identifiseer. 'n Omvattende literatuuroorsig is uitgevoer wat die gebied van Fisiese Batebestuur en Sosiale Netwerkanalise aanspreek. Die literatuuroorsig is aangevul deur onderhoude met kundiges op die gebied van Fisiese Batebestuur. Sodoende kon die uitdagings van Fisiese Batebestuur bestudeer word in die konteks en vermoëns van Sosiale Netwerkanalise, en gevolglik is die belangrikste beperkings in Fisiese Batebestuurstrategie-Uitvoering geïdentifiseer. Die voorlopige resultate van die studie het bevind dat gebrekkige inligtingsvloei en swak besluitneming die hoofbeperkings is wat die uitvoering van 'n Fisiese Batebestuurstrategie kan verhinder. Gevolglik is 'n Sosiale Netwerkanalise toepassingsmetodiek ontwikkel om dié probleemareas onder die mikroskoop te plaas. Dié metodiek is dan op twee teiken-aanlegte in die Suid-Afrikaanse Mynbou Industrie toegepas. Netwerkdataby vir die studie is deur middel van meningsopnames in Junie en Julie 2012 ingesamel. Die gevallestudies demonstreer dat 'n Sosiale Netwerkanalietoepassing in Fisiese Batebestuur waardevolle resultate kan lewer met

betrekking tot die probleme wat ondervind word in die uitvoer van Fisiese Batebestuurstrategie. Onder die belangrikste bevindings van die Sosiale Netwerkanalise tel die oorbelasting van sleutelpersoneel, mislukte samewerking, asook eksessiewe interdepartementele samewerking met die potensiaal om die uitvoering van die Fisiese Batebestuurstrategie te verhinder. Die bevinding is deur dialoog met die individuele deelnemers in die ondersoek gestaaf. Die studie het bevind dat Sosiale Netwerkanalise geskik is as 'n metode om die primêre beperkings, wat ondervind word in die uitvoering van Fisiese Batebestuurstrategie, te identifiseer. Dit moet egter ook beklemtoon word dat daar belangrike voorvereistes bestaan, wat vir die suksesvolle toepassing van Sosiale Netwerkanalise in plek moet wees. Toekomstige navorsing kan gebaseer word op die uitkoms van dié tesis met die doel om ontwerpverbeteringsplanne vir die teiken-aanlegte op te stel. Daarbenewens kan 'n moontlike opvolg Sosiale Netwerkanalise uitgevoer word om te meet of die beperkings wat deur die ondersoek geïdentifiseer is, voorkom is.

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The Author

September, 2012

Dedications

*This thesis is dedicated to my parents
Helga and Burkhard,
for their uncompromising support, trust and love.*

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List of Abbreviations

| | |
|--------|--|
| AAPL | Anglo American Platinum Limited |
| ACRG | Asset Care Research Group |
| AMS | Asset Management System |
| BSi | British Standards Institution |
| CAPEX | Capital Expenditures |
| FMEA | Failure Mode and Effect Analysis |
| GM | General Manager |
| IAM | Institute of Asset Management |
| ISO | International Organisation for Standardisation |
| KPI | Key Performance Indicator |
| MD | Managing Director |
| OED | Oxford English Dictionary |
| PAM | Physical Asset Management |
| PAMS | Physical Asset Management Strategy |
| PAMSE | Physical Asset Management Strategy Execution |
| PAS 55 | Public Available Specification 55 |
| SNA | Social Network Analysis |

Notation

Notation for Social Network Data

| | |
|-----------------|---|
| V | Set of values v_i |
| \mathcal{G}_V | Valued graph |
| \mathcal{S} | Social network that is defined by the collection of S , \mathcal{G}_d and \mathbf{X} |
| \mathcal{L} | Set of lines l_i |
| l | Line i that connects an actor pair |
| g | Number of actors |
| \mathcal{G}_d | Directed graph |
| \mathcal{N} | Set of nodes n_i |
| n_i | Node or actor i |
| S | Algebraic structure, consisting of \mathcal{N} and \mathcal{L} . Standard representation of the simplest possible network |
| x_{ij} | Element of the $g \times g$ sociomatrix \mathbf{X} |
| \mathbf{X} | Sociomatrix with $g \times g$ elements |
| L | Number of arcs |
| \mathcal{X}_r | Relation r |
| \mathcal{X}_1 | Relation of information exchange |
| \mathcal{X}_2 | Relation of PAM information exchange |
| \mathcal{X}_3 | Relation of trust |
| \mathcal{X}_4 | Relation of advice indecision making |
| \mathcal{X}_5 | Relation of approval in decision making |

Notation for Network Properties and Structural Calculations

| | |
|------------|---|
| Δ | Density |
| Δ^V | Density calculated on data of valued numeration |

| | |
|---|--|
| $d(n_i)$ | Nodal degree of node n_i |
| $d_I(n_i)$ | Indegree of node n_i |
| $d_O(n_i)$ | Outdegree of node n_i |
| $d(n_i, n_j)$ | Geodesic distance between two nodes n_i and n_j . Number of lines in the geodesic g_{ij} linking n_i and n_j |
| $C_D(n_i)$ | Degree centrality of a node n_i |
| $C'_D(n_i)$ | Standardised degree centrality of a node n_i |
| C_D | Degree centralisation |
| $C'_C(n_i)$ | Standardised closeness centrality of a node n_i |
| $C_C(n^*)$ | Largest observed value of $C'_C(n_i)$ |
| C_C | Closeness centralisation |
| $C_B(n_i)$ | Betweenness centrality of a node n_i |
| C_B | Betweenness centralisation |
| g_{jk} | Geodesic between two nodes n_j and n_k |
| $g_{jk}(n_i)$ | Geodesic between two nodes n_j and n_k that include node n_i |
| \mathbf{e} | Vector of eigenvector centralities |
| e_i | Eigenvector centrality of node n_i |
| λ | Largest eigenvalue of a symmetrical sociomatrix |
| $x^{(n)}$ | Authority weight |
| $y^{(n)}$ | Hub weight |
| $P_D(n_i)$ | Prestige |
| $P'_D(n_i)$ | Standardised prestige |
| I_i | Input domain of actor n_i |
| $P_P(n_i)$ | Proximity prestige of actor n_i |
| $d_1(i, j)$ | Dissimilarity measure |
| \mathbf{D} | Dissimilarity matrix |
| N_i | Set of all neighbours of node n_i |
| $\Delta_{\mathcal{B}_\alpha \rightarrow \mathcal{B}_\beta}$ | Block density between the classes \mathcal{B}_α and \mathcal{B}_β |
| $\Delta^V_{\mathcal{B}_\alpha \rightarrow \mathcal{B}_\beta}$ | Valued block density between the classes \mathcal{B}_α and \mathcal{B}_β |
| $P_{\mathcal{B}_\alpha \rightarrow \mathcal{B}_\beta}$ | Proportion of resource exchange interaction in a block. |
| $p_{\mathcal{B}_\alpha \rightarrow \mathcal{B}_\beta}$ | Proportion of resource exchange interaction of class \mathcal{B}_β |

Essential Concepts

Physical Asset(s)

Plant infrastructure, machinery, property, buildings, vehicles and other items that have a distinct value to the organisation.

Physical Asset Management (PAM)

Systematic and coordinated activities and practices through which an organisation optimally and sustainably manages its physical assets and asset systems, their associated performance, risks and expenditures over their life cycles for the purpose of achieving its organisational strategic plan.

Physical Asset Management Strategy (PAMS)

A long-term optimised approach to the management of physical assets, derived from, and consistent with, the organisational strategic plan and the physical asset management policy.

Physical Asset Management Strategy Execution (PAMSE)

The process of translating the physical asset management strategy aspirations into workable actions and managing strategic initiatives through the allocation of resources, coordination of responsibilities and accountabilities, while continuously reviewing, adapting and communicating this very process.

Social Network

Social entities (e.g. people) and the information on the relationships (e.g. friendship or information exchange) between them.

Social Network Analysis (SNA)

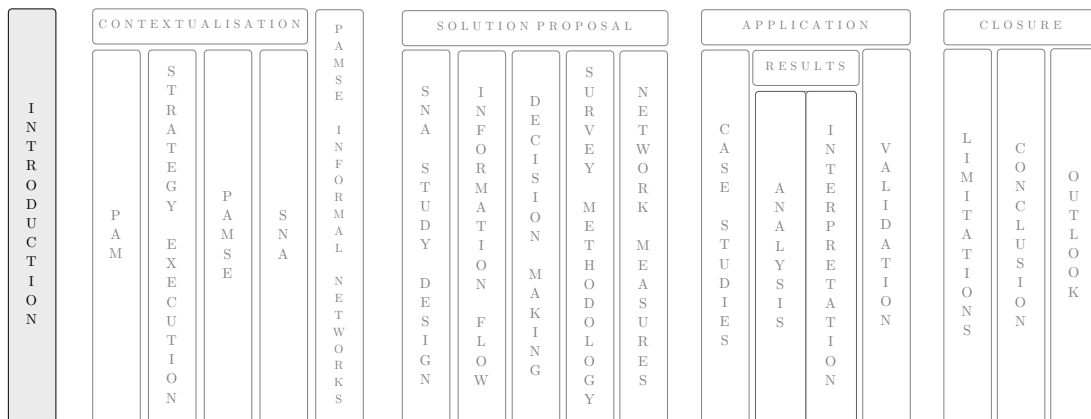
Research paradigm and the collection of techniques for the analysis of social networks.

Chapter 1

Introduction

Chapter Aim:

The aim of this chapter is to introduce the intersection of present challenges in Physical Asset Management (PAM) and the matching capabilities of Social Network Analysis (SNA). From this context a clear problem statement and sequence of research objectives can be derived. The research aspirations shall be embedded in an adequate research design and methodology, in order to address the central research question.



Chapter Outcomes:

- Delineation of the research domain and research problem.
- Presentation of the pursued research objectives.
- Delimitation of the study.
- Adequate research design and methodology.
- Development of the thesis blueprint.

1.1 Introduction

Physical assets include plant infrastructure, machinery, vehicles and other items that are of distinct value to an organisation. For many organisations, physical assets are the primary means of revenue generation. In particular, the heavy industries rely on a built infrastructure as the principle means for operation and service delivery. The purpose of Physical Asset Management (PAM) is to ensure the service delivery and the most effective use of physical assets. Waeyenbergh and Pintelon (2002) state that high speed technological innovation, combined with severe competition, shortens the equipment lifecycle and puts equipment under higher stress. Mitchell (2007) explains that in some industries, demand is such that maximum production capacities are required, while other industries in turn, experience excess capacity and have to focus on their financial sustainability. The elevated tempo, intensity and volatility of operations demand the compliance of physical assets to the defined service targets. Consequently, the effective management of physical assets turns into an important driver for profitability and business success. The purpose of PAM boils down to the *support of the organisational strategic plan*.

Woodhouse (2006) points out that physical assets have been managed for many years, but that the scope of their management has undergone a significant shift. Amadi-Echendu *et al.* (2010a) recognise that around the year 2000 a growing interest in generalising PAM, and thus moving away from the focus on the traditional areas of asset maintenance, became apparent. According to Woodhouse (2006), organisations realised that by working through functional silos major opportunities were missed. Ever since this realisation, the argument for an interdisciplinary approach of PAM in order to ensure that an appropriate mix of skills can be brought to resolve the vexed issue of PAM, has been made. *Effective PAM cuts across organisational functions*.

Despite cross-functionality and alignment to an organisation's strategic plan, the role of employees surfaces as a vital element in successful PAM. In particular, Tsang (2002) points to human dimensions as a key issue for the successful management of physical assets. Woodhouse (2006) puts forward that PAM is achieved through tools, techniques as well as restructuring and performance measures but that it is ultimately the employees that achieve the defined targets. In the words of John S. Mitchell (2012):

“You have to know technology to do it, but you will have to understand people to get it done.”

Today's PAM transcends the traditional organisational boundaries and myopia. The contemporary perspective on PAM highlights a multidisciplinary skill set, cross-functionality and targets organisational synergies. The prevalent threats, from traditional paradigms, silo mentality and communication deficiency, shifted towards an integrated view that especially emphasises the strategic and human dimension. This fairly young approach has been shared among researchers and practitioners alike and matured with the publication of the Public Available Specification 55 (PAS 55).

PAS 55 is a guiding framework for PAM that has been published by the British Standards Institution (BSi). PAS 55 joins the international consensus on PAM and can be seen as the blueprint of the present interpretation of PAM. A detailed introduction to PAS 55 is undertaken as part of the literature study, for now, it is purposeful to extract the concepts inherent to the guideline. Figure 1.1 illustrates the definition of a Physical Asset Management Strategy (PAMS), that serves the achievement of the organisational strategic plan. For example, the organisational strategic plan may seek to achieve a 10% increase of the production output by the end of next year. Because the organisation draws extensively on process infrastructure to achieve the desired production outputs, the management of physical assets plays a crucial role in achieving the strategic goals. In order to facilitate the organisation's aspirations, a PAMS is established. The PAMS comprises of an approach to the management of physical assets that is directed towards achieving the defined target(s), in this case, the increase of the production output. This approach involves a myriad of employees, processes and physical assets, that, when connected evolve into action that leads to tangible outcomes and the attainment of strategic targets.

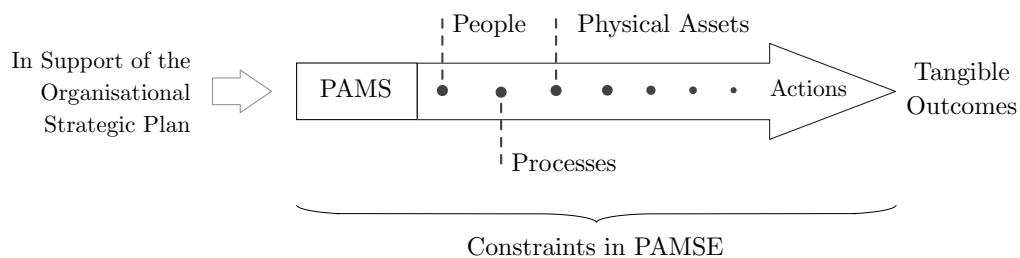


Figure 1.1: Principle understanding of PAMSE.

An example of this approach is where the organisation may decide to review ineffective work processes that surround the maintenance of its physical assets, in order to improve their care and avoid breakdowns. There may also be a number of critical machines that repeatedly fail because of overheating, therewith causing the organisation to suffer the loss of valuable production time. In this case, the organisation

may decide to dispose outworn cooling systems and acquire newer technology. The intention of both measures is directed at a common strategic goal. Ideally, the PAMS is achieved through a goal-oriented combination of strategic initiatives, rather than a collection of disjointed improvement projects. Strategic initiatives are directed at a common purpose and the process of carrying them out is, in essence what Physical Asset Management Strategy Execution (PAMSE) entails. PAMSE is the process of translating the PAMS aspirations into workable actions and managing strategic initiatives.

Figure 1.1, however, clarifies that the strategy execution process is accompanied by constraints. Research by Kaplan and Norton (2008) highlights that 60 to 80% of all companies fall short of the strategic targets that have been set. Moreover, Zook and Allen (2001) find that 90% of all companies fail to realise strategic ambitions. The success rate of strategy execution is daunting. Strategy execution failure appears to be a common dilemma and the strategy execution process appears to be prone to failure. One reason for collapse may be the lack of attention that the subject of strategy execution receives. The management literature and renowned researchers such as Kaplan and Norton (2001) acknowledge that for long, the properties of strategy execution have been left unattended by the research community. It has also been highlighted that the most carefully prepared strategic plan fails if it is not executed sophisticatedly. A brilliant strategy is meaningless if the intention of the strategy can not be delivered. No strategy can succeed if not executed successfully. *Successful strategy execution is imperative.*

In a similar way this lack of attention can be found in the body of knowledge in PAM. To date, the literature, as well as frameworks such as PAS 55 mainly focus upon devising strategies, but the properties of strategy execution remain vastly disregarded. Not much research has been concerned with influences that affect the process of materialising the PAMS. The present attempts often lack scrutiny and depth in investigations. Publications in PAM often focus on asset life cycle activities and on parading new methodologies for planning, assessment and optimisation purposes, see for example Hastings (2009) and Amadi-Echendu *et al.* (2010a). It seems that the field of PAM is dominated by strategic planning and technical management, focussing on system optimisations and defect elimination through methodologies such as Failure Mode and Effect Analysis (FMEA) and Criticality Analysis. However, the link between strategic ambitions and asset life cycle measures is largely missing. It appears that PAM falls short in addressing the properties of PAMSE, thus ignoring a salient reason for the failure to succeed.

Publications of management research do, however, elucidate a number of constraints that can stifle the strategy execution process. Throughout the literature, the prevalence of particular areas of concern becomes apparent. Especially the research of Hrebiniak (2006) and Neilson *et al.* (2008) which yields growing insight into primary problem areas of strategy execution from which there is much to gain. Compellingly, a number of authors highlight *ineffective information flows and decision making as the primary constraints* in strategy execution. Moreover, the presence of similar problems is consistently echoed by texts in PAM and the experience of practitioners. However, PAM continues to pay poor attention to the factors that may limit its success. This study aims at filling this void.

The interplay of the above factors leads up to the distinct problem composition illustrated in Figure 1.2. Most importantly, it can be said that the PAMSE cuts across organisational functions and that its success is imperative. Furthermore, major obstacles to PAMSE are likely to be found in the spheres of information flows and decision making. When brought together, these factors significantly complicate efforts of PAM. Because PAM involves a multifaceted field of responsibility, that transcends the organisational boundaries, the task of unraveling the information flows and the decision making within the organisation seems insoluble.

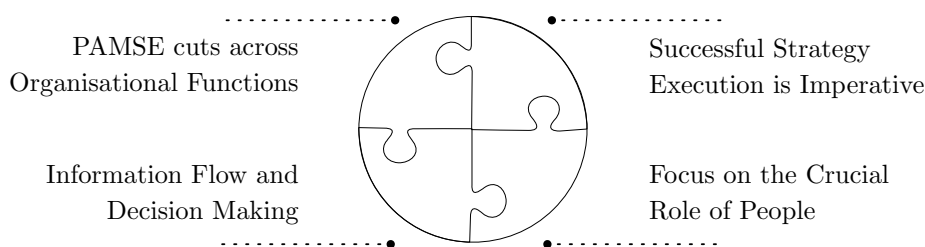


Figure 1.2: Problem composition.

Strategic PAM initiatives may require individuals and processes to change and adapt in some or other way. Mitchell (2007) underscores that organisational conflicts in change processes surrounding PAM are typically more pervasive and difficult to solve than technical issues. Correspondingly, Amadi-Echendu *et al.* (2010a) expect major PAM challenges to most likely arise from the human dimension, in organisational settings and associated cognitive dispensations. However, the famous German physicist Albert Einstein once said:

“In the middle of difficulty lies opportunity.”

PAMSE is complex, but an improved capability of executing the strategic aspirations has the potential to yield great benefits for the organisation. The first step towards addressing the challenges of good PAMSE is to understand the obstacles to its success. Therefore, this thesis draws on the management literature's findings on problems in strategy execution and projects them onto the field of PAM. Within the domain of PAMSE, Fogel (2012*b*) identifies ten areas of opportunity, of which a selection is shown in Table 1.1.

Table 1.1: Selected areas of opportunity in PAMSE.

-
-
- Managing change effectively.
 - Understanding power or influence and then using it for execution success.
 - Exercising execution based leadership.
 - Developing organisational structures that foster cooperation, information sharing and coordination, without losing accountability.
 - Developing effective metrics, measurement systems and feedback mechanisms.
-
-

Adapted from Fogel (2012b).

The knowledge about potential constraints and areas of opportunity in the execution process is only one of the challenges. The inability to keep track of the constraints and possible opportunities inside the organisation, significantly hampers effective action to find solutions. The resources of an organisation are limited and reference points are required to direct actions to where they can be most effective. The question is, whether there is a method which is able to elucidate the primary constraints in PAMSE and thus enables management to engage in corrective action. Fogel (2012*b*) shows that the development of effective metrics is an area of opportunity. Additionally, the PAM guideline, PAS 55¹ advises to continuously consider improvement opportunities through new techniques and practices, particularly in achieving the PAMS in more effective ways.

The fact that PAM is tightly meshed across many functions inside an organisation, complicates investigations and calls for a method of analysis that pays attention to its agency wide character. Moreover, it has been shown that PAM is achieved by people and not by machines and processes. As Tsang (2002) argues, the understanding of working dynamics and parameters of group effectiveness will yield bet-

¹See section 4.3.2 i) in BSi (2008*a*, p.8) and section 4.3.1 g) in BSi (2008*b*, p.7)

ter organisational design. This will then foster employee commitment and greater chances of success in organisational change. Ideally, the mode of analysis allows for the investigation of major constraints that have been highlighted by the literature. Hence, a potential mode of analysis has to comply with the following requirements:

- Capture problems in cross-functional organisational settings.
- Have a particular focus on the human dimension.
- Be capable of analysing information flows and decision making.

These requirements give rise to Social Network Analysis (SNA) as a possible method to map the problems in PAMSE, potentially enabling corrective action. SNA is a research paradigm and collection of methods used to analyse the structure of social networks. SNA may be best introduced by a simple example: consider a fictitious open cast mining operation that comprises of a collection of employees. Notwithstanding an individual's occupation, the employees may be connected by diverse relationships; some may be good friends and others are members of the same sports club. Yet, it can be decided to focus on *one specific* relationship that connects two individuals. In terms of this thesis, it may be asked who exchanges information with whom. If every employee at the mine is pictured as a node and each "information exchange" relationship is depicted as a connecting line between two individuals, then a social network which describes the information exchange at the mine emerges, see exemplary Figure 1.3. In short, a social network consists of a collection of social entities and the information on the relationships between them. SNA offers useful means to investigate the tie structure of this network, producing insight in how the information flows between people in a mining operation.

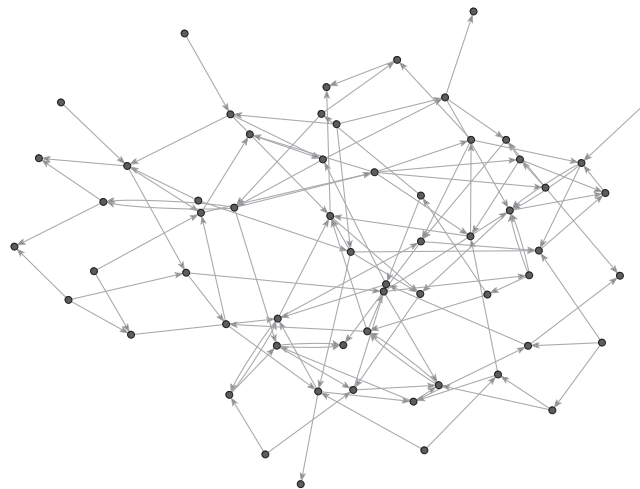


Figure 1.3: Example of a social network graph.

The concepts of SNA have been around for a long time, but according to Carrington *et al.* (2005), it was only in the 1990s that the interest and use of different methodologies in SNA increased. Different sciences and industries advocated the application of SNA, and organisational SNA studies became part of management research. The applications of SNA range over a vast area of different fields. Carrington and Scott (2011) present an exhaustive list of applications in disciplines such as social psychology, social anthropology, communication science, organisational science, economics, geography and sociology.

Cross *et al.* (2010a)² show that publications in the area of organisational SNA applications demonstrate how the method can yield insights into the dynamics inside an organisation. Numerous studies promote SNA as a method to visualise and understand the myriad of relationships that can either facilitate or impede information flows and decision making. Moreover, SNA is able to pinpoint individuals in a network, whose connectivity elevates them into a particular influential positions. Chinowsky *et al.* (2010) demonstrate that lately, the method also receives attention within the engineering and project management field. The authors utilise SNA in order to discern communication barriers between the regional and corporate offices of a structural engineering organisation. Cross *et al.* (2001) conduct a SNA of executives in the exploration and production division of a large petroleum organisation. The analysis yielded an array of problem areas that limited the flow of information among executives and thus needed to be addressed.

An application of SNA may be particularly suitable for the PAM environment. SNA complies with the three requirements, stated above. PAM is a cross-functional undertaking and the investigation into the constraints in PAMSE has to harness means to consider cross-functional relationships. SNA is not attached to an organisation's formal structure or process, it disregards hierarchical relationships and breaks through formally defined working structures. Instead, SNA focusses on the so called "informal organisation"; the empirically determined relationships that exist between people, as opposed to relationships that are implied by the formal organisational structure. Hence, SNA reflects on the actual working dynamics between people. This leads to the second reason which advocates the use of SNA. While the human dimension is repeatedly highlighted as a key factor for success and immense challenge, the methods of SNA have been proven to adequately reflect on the dy-

²Rob Cross is a head figure in the application of SNA in organisational settings. He is professor at the University of Virginia and research director of the "Network Roundtable", a consortium of over 100 organisations which sponsor research on network applications to critical management issues. The recent publication Cross *et al.* (2010a) assemble various applications of SNA in organisational settings.

namisms that accompany the human dimension. Furthermore, publications indicate that SNA is capable of grasping problems in the domains of strategic alignment, information exchange, decision making and organisational change (exemplary, see Krackhardt and Hanson (1993), Haythornthwaite (1996), Cross *et al.* (2002a) and Colella (2010), Cross *et al.* (2010b)).

The role of PAMSE is imperative to the success of PAM, and the identification of constraints in PAMSE can provide the cornerstone for effective corrective action. SNA pays heed to the traits of the PAM field and is evidently capable of addressing problem areas that may be primary constraints in PAMSE. Moreover, SNA appears to be able to cater for some of the areas of opportunity in PAMSE. For that reason, SNA may be an adequate means to unveil constraints in PAMSE. A beneficial application of SNA in PAM may ultimately yield novel means to support a more effective deployment of the PAMS. Therefore, this thesis investigates SNA as a method to map primary constraints in PAMSE. The research domain of this thesis is accordingly illustrated in Figure 1.4.

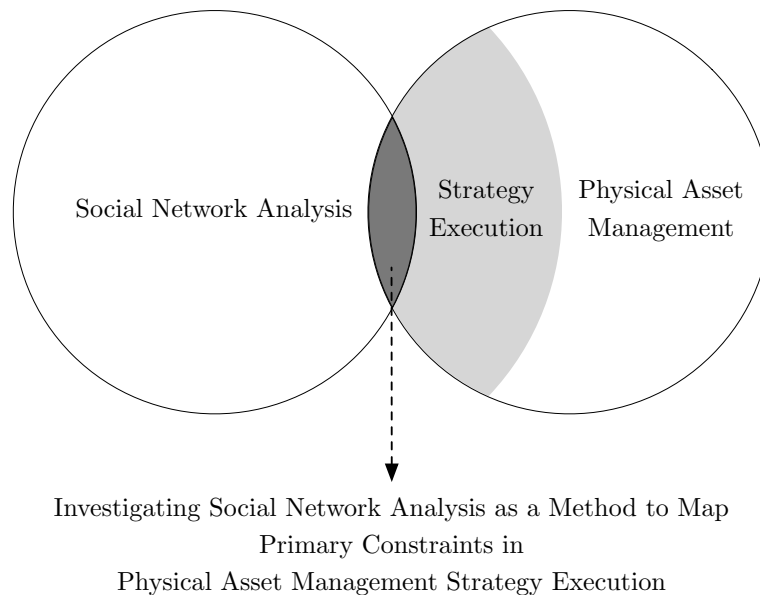


Figure 1.4: Research domain.

1.2 Problem Statement

There is a gaping void in the PAM body of knowledge. The PAM literature is dominated by strategic planning and numerous methods for asset lifecycle activities, but virtually no research has focussed on the problem areas that accompany strategy execution efforts³. Yet, it is emphasised that strategy execution is imperative for success. In spite of the fact that management research provides significant insight into major problem areas and although PAS 55 highlights important enablers and recommendations of good PAM, the means to detect constraints in PAMSE are deficient. The knowledge of potential constraints is only one side of the coin, the inability to locate them inside the organisation hampers the ability to direct corrective action to where it is needed the most. There is great opportunity inherent in pin-pointing PAMSE constraints inside the organisation. Once constraints are mapped, they can be resolved more effectively. This may lead to improved execution outcomes, enhanced achievement of strategic PAM goals and eventually yield substantial benefits to the organisation.

In addition, the motivation for this thesis is based on a number of grounds. BSi (2008b, p.7) suggests constantly considering constraints and new opportunities to achieve the strategy in more effective ways. Stewart *et al.* (2003) also suggest developing strategies and recommendations for the effective deployment of PAM initiatives. In order to comply with the requirements of the human dimension, Amadi-Echendu *et al.* (2010b) call for the use of more qualitative modes of analysis. Further, the previous section demonstrates that SNA has qualities that match the characteristics and challenges in PAM. Additionally, publications prove that SNA is able to examine the subjects of information flow and decision making, which can presumably become two major constraint in PAMSE.

In the light of the demands of PAM and the matching qualities of SNA, the purpose of this thesis is the investigation of SNA as a diagnostic tool for PAMSE. This will enable the promotion of PAMSE processes and potentially increase the effectiveness of the working structures surrounding execution efforts. The research domain mirrors the current traits of PAM and addresses overdue challenges in the field:

The problem is that the means to detect primary constraints in physical asset management strategy execution are deficient.

³See for example Stewart *et al.* (2003), BSi (2008a), BSi (2008b) Hastings (2009), Amadi-Echendu *et al.* (2010a).

The purpose of this thesis is to examine SNA as a method to map primary constraints in the execution of the PAMS. Therefore, SNA will be applied in an PAM environment, aiming to capture informal networks that visualise the dynamics and working structures inside the organisation and ultimately elucidate constraints in PAMSE. This points towards the central empirical research question, that is shown below, and the null hypothesis H_0 , defined in Table 1.2.

Can SNA be used as a method to map primary constraints in physical asset management strategy execution?

Table 1.2: Null hypothesis.

H_0 : Social network analysis can not be used as a method to map primary constraints in physical asset management strategy execution.

1.3 Delimitation

In exploring new areas of research, it is imperative that boundaries are put in place. The introduction outlined the theoretical position of this thesis. This section explicitly sets the boundaries of this study.

This thesis focusses essentially on the field of PAM and the findings are strictly within this context. Moreover, strategic management draws a conceptual distinction between the strategic management processes of planning, implementation and evaluation. According to Hrebiniak (2006), these processes are separate, distinguishable parts of the strategic management process that can be differentiated and discussed separately, conceptually and practically. The stance that these processes can be distinguished conceptually has gained grounds. Robbins and Coulter (2012) illustrate that the view is anchored in management literature. While the different processes may be regarded separately, Hrebiniak (2006) stresses the importance of their interdependence. Albeit, Martin (2010) expresses considerable criticism in viewing strategy and its execution as distinct from one another. For the purpose of this thesis a clear conceptual distinction is drawn. This thesis explicitly limits itself to discussing the aspects of strategy execution. Since this thesis is concerned with the discipline of strategy execution only, there is no reason to elaborate and analyse the surrounding disciplines such as strategy planning or formulation. Nevertheless, the study acknowledges the interdependencies of the different strategic disciplines. There

may be a variety of ways in which constraints in strategy execution can be detected. These do not fall into the focus of this thesis and will not find consideration at any point. SNA is the exclusive subject of investigation for the purpose of this study. It is important to point out that this thesis aims at detecting primary constraints in PAMSE. Resolving the problems, which become evident, falls outside the scope of this thesis. In summary, the following boundaries apply to this thesis:

- The thesis is bound to the field of PAM.
- The thesis focusses solely on the execution of a strategy.
- The thesis only investigates SNA as a solution to the stated problem.
- The thesis does not attempt to solve constraints once they have been disclosed.

1.4 Research Objectives

This thesis builds upon a series of research objectives to ultimately achieve a comprehensive answer to the stated research question. The sequence of research objectives splits the central research question into more manageable sub-tasks that are addressed subsequently.

The first research objective is to capture the fundamentals of the key concepts that build the research domain of this thesis. An exhaustive literature review provides a thorough understanding of PAM, the concept of strategy execution and PAMSE. In doing so, the literature review combines insight from publications in management science and PAM. The next objective is to single out the primary constraints in PAMSE from the great variety of constraints that are brought up by publications in PAM and management research. Because there are few publications that specifically concern strategy execution in PAM, the literature review is supported by qualitative research methods. Furthermore, the literature review provides a sound understanding of SNA. Chapter 2 concludes with a discussion of SNA's ability in addressing the distilled problem areas of PAMSE. The chapter paves the way for the development of an approach for the application of a SNA.

Chapter 3 pursues the single research objective of constructing a robust SNA application methodology. The application methodology builds on the findings from the literature review and is derived from the leading texts⁴ in SNA, forging an adequate methodological concept.

⁴The leading text in the field include the work by Wasserman and Faust (1994), Scott (2000) and Scott and Carrington (2011).

Chapter 4 involves SNA case studies and pursues three research objectives. Firstly, it is desired to apply the developed SNA application methodology at the case study research sites. The second objective is to map primary constraints in PAM strategy execution at the research site. Penultimately, it is the objective to validate the SNA results. This thesis' ultimate research objective is strived for in Chapter 5. The final research objective is to draw a conclusion from the analyses in Chapter 4 which should answer the central research question: the defined null hypothesis is tested and consequently rejected or accepted. The corresponding sequence of research objectives for this thesis is shown in Table 1.3.

Table 1.3: Sequence of research objectives.

| |
|---|
| <i>Chapter 2</i> |
| 1. Establish the fundamentals of PAM and PAMSE. |
| 2. Single out the primary constraints in PAMSE. |
| 3. Provide a sound understanding of SNA. |
| 4. Contextualise the findings from PAMSE and SNA. |
| <i>Chapter 3</i> |
| 5. Construct a robust SNA application methodology. |
| <i>Chapter 4</i> |
| 6. Apply the developed SNA application methodology. |
| 7. Map primary constraints in PAMSE at a research site. |
| 8. Validate the analysis results. |
| <i>Chapter 5</i> |
| 9. Draw conclusions from the analysis that answer the central research question and determine the acceptance or rejection of the null hypothesis. |

1.5 Research Design and Methodology

The research design is the blueprint of the intended research process. Creswell (2009) explains that it encompasses the intersection of philosophical assumptions, strategies of enquiry and specific research methods. Strategies of inquiry cover the decisions about qualitative, quantitative or mixed methods designs that guide the procedures of research. The research methods are comprised of data collection, analysis and

interpretation. In the following section the research design for this thesis is presented. The framework that guides its development is shown in Figure 1.5.

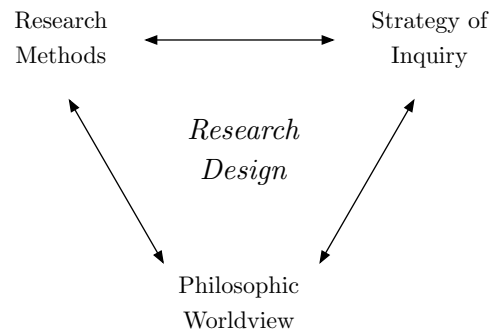


Figure 1.5: Research design framework.

Adapted from Creswell (2009).

1.5.1 Research Design

Commonly, there is a distinction drawn between qualitative and quantitative research. Newman and Benz (1998) suggest that the two approaches are not dichotomies but two different ends of a continuum. Research tends to be either more qualitative or more quantitative. The decision to emphasise one particular research approach is determined by the topic under investigation. Creswell (2009) explains that the exploratory nature of qualitative research is of benefit when little research is done in a certain field. In line with this statement, qualitative research is used to supplement the few publications in PAM and to understand the obstacles that ascribe problem areas in PAMSE. Even though the paradigm of SNA is rooted in the qualitative assumptions of sociology and the exploring and understanding of social phenomena, its application requires the collection of quantitative data and the quantitative examination of structural variables. After quantitative research has been done, the study will return to a qualitative research approach. The research results from quantitative data analysis are validated in cooperation with the individuals that formed the subject of analysis. Individuals are approached using qualitative methods of inquiry in order to obtain their opinions regarding the research results.

Hence, this thesis combines qualitative and quantitative research approaches. Initially, the approaches are used separately to frame the investigation, but eventually they are applied together to answer the central research question. The mix of qualitative and quantitative methods brings together different data sources and findings are based on the convergence of both types of data, which forms an integrated

solution. The research design in this thesis is based on mixed methods research. Because the quantitative and qualitative means expand on the findings of their respective predecessor, the strategy of inquiry can be defined as a *sequential mixed methods research design*.

1.5.2 Philosophic Worldview

Slife and Williams (1995) find that the philosophical ideas remain largely concealed in research. Due to the fact that they influence the practice of research, Creswell (2009) suggests making the espoused philosophical ideas explicit.

The basic set of beliefs that guide the action of this thesis is the *pragmatic worldview*. Rossman and Wilson (1985) explain that pragmatism uses all approaches available to understand a problem, it places a special emphasis on the research problem rather than on methods. According to Creswell (2009) this worldview arises out of actions, situations and consequences rather than antecedent conditions. Further, the author demonstrates that multiple studies⁵ convey the problem-centred character of pragmatism and promote the use of pluralistic research methods for investigation, underpinning the mixed methods research design.

The adoption of a pragmatic worldview is at the heart of the approach of this thesis. The research problem is embedded in the field of PAM, while the research paradigm of SNA originates in the social sciences. Hence, a solution is chosen according to the particular problem which is faced and even though the problem exists within PAM, a solution from another distinct discipline is considered. This thesis crosses the traditional boundaries of the field of PAM in employing methods that have their roots in a very different and traditional discipline. The researching community demonstrates that this mindset is widely practiced: Carrington and Scott (2011) explain that although SNA is a well defined paradigm in its own, it finds application across traditional disciplines.

1.5.3 Reasoning Methods

Two different reasoning methods could be identified in this thesis. The research hypothesis as well as the major problem areas in PAMSE are *deductively derived* from the premises discovered during the literature review. When drawing on the findings from interviews and by answering the central research question, *inductive generalisation* is applied. The insight from expert interviews are logically applied

⁵As presented by Creswell (2009), see Rossman and Wilson (1985), Tashakkori and Teddlie (1998) and Morgan (2007).

concurrently to form conclusions about the properties of PAMSE. From the the validated results of the SNA application, inferences are made that concern the wider field of PAM. Deductive reasoning, as well as inductive generalisation reasoning methods are used throughout this study.

1.5.4 Research Methods

The research design advocates the use of qualitative and quantitative research methods. The first *qualitative* research step begins with the purposeful selection of interview partners. In structured⁶ face-to-face interviews, participants are presented with open-ended questions regarding strategy execution in PAM. The interview documentation is provided in Appendix B. The *quantitative* component of the mixed methods research design involves the SNA application that builds on survey research. SNA is applied in two case studies in a PAM environment. The collected data is analysed using the social network software “Pajek”⁷ as well as “Microsoft Excel” and “Matlab”. The case study results are reviewed and validated using *qualitative* research methods. Survey participants are purposefully selected and informed regarding specific analysis results. Individuals are contacted using email or telephone in order to collect qualitative documents. Due to the sensitivity of information the decision was taken to not disclose the correspondence with particular individuals. On the basis of the reviewed and validated analysis results, the central research question can be discussed. The decisions regarding research methods complete the intended research process. The blueprint of the developed research design is illustrated in Figure 1.6.

| | Research Approach | Research Method | Research Objective | Chapter |
|--------------------------------|-------------------|-----------------------------------|---|---------|
| Sequential Methods Research | Qualitative | • Structured personal interviews | Single out the primary constraints in PAMSE | 2 |
| | Quantitative | • Survey research • SNA | SNA application | 4 |
| Mixed Methods Research | Qualitative | • Qualitative document collection | Validation of analysis results | 4 |

Figure 1.6: Research design blueprint.

⁶Interviews are conducted in a structured manner as far as is possible. In some cases it may be adequate to diverge from the prepared questions.

⁷Information regarding the software is accessible online: <http://pajek.imfm.si/doku.php>

1.6 Thesis Layout

The document layout is logically aligned with the sequence of the research objectives and corresponds to the stated research design. The chapters are organised in a way that enable the reader to best comprehend the flow of the research. In addition to the chapter outline below, Figure 1.7 integrates the chapter overview with the stated research objectives (see Table 1.3) and illustrates how the mixed methods research approach (see Figure 1.6) ties in. Figure 1.7 is the blueprint for the progression of this thesis.

Chapter 1: Introduction

Chapter 1 is the introductory section which describes the architecture of this thesis. The chapter states the research domain and provides a problem statement which is translated into research objectives and a research design and methodology. Lastly, the chapter produces a thesis layout and renders a blueprint for the progression of this thesis.

Chapter 2: Literature Review and Contextualisation of the Study

Chapter 2 introduces the fundamentals of PAM, strategy execution, PAMSE and SNA. It singles out the primary constraints in PAMSE and contextualises the findings with the capabilities of SNA. The chapter paves the way for a SNA application that attempts to map the primary constraints in PAMSE.

Chapter 3: Social Network Analysis Application Methodology

Chapter 3 presents a SNA application methodology that is tailored according to the findings of Chapter 2. It outlines the application framework, as well as the SNA study design, conceptualises the survey methodology and introduces the structural variables and network properties to be analysed. Chapter 3 is the backbone for the analysis of the case studies.

Chapter 4: Case Studies

Chapter 4 is the final body of the research. The chapter introduces the case studies' preliminaries. Thereafter, the chapter presents and reviews the SNA application results. Chapter 4 then engages in the validation of research results. Consequently, the research results are discussed and validated.

Chapter 5: Conclusion and Recommendations for Future Research

Chapter 5 reflects on the conducted research concisely and presents the limitations of the study. Thereafter, the final conclusion is drawn, thus answering the central research question and testing the null hypothesis. The thesis concludes with an outlook and makes recommendations for future research.

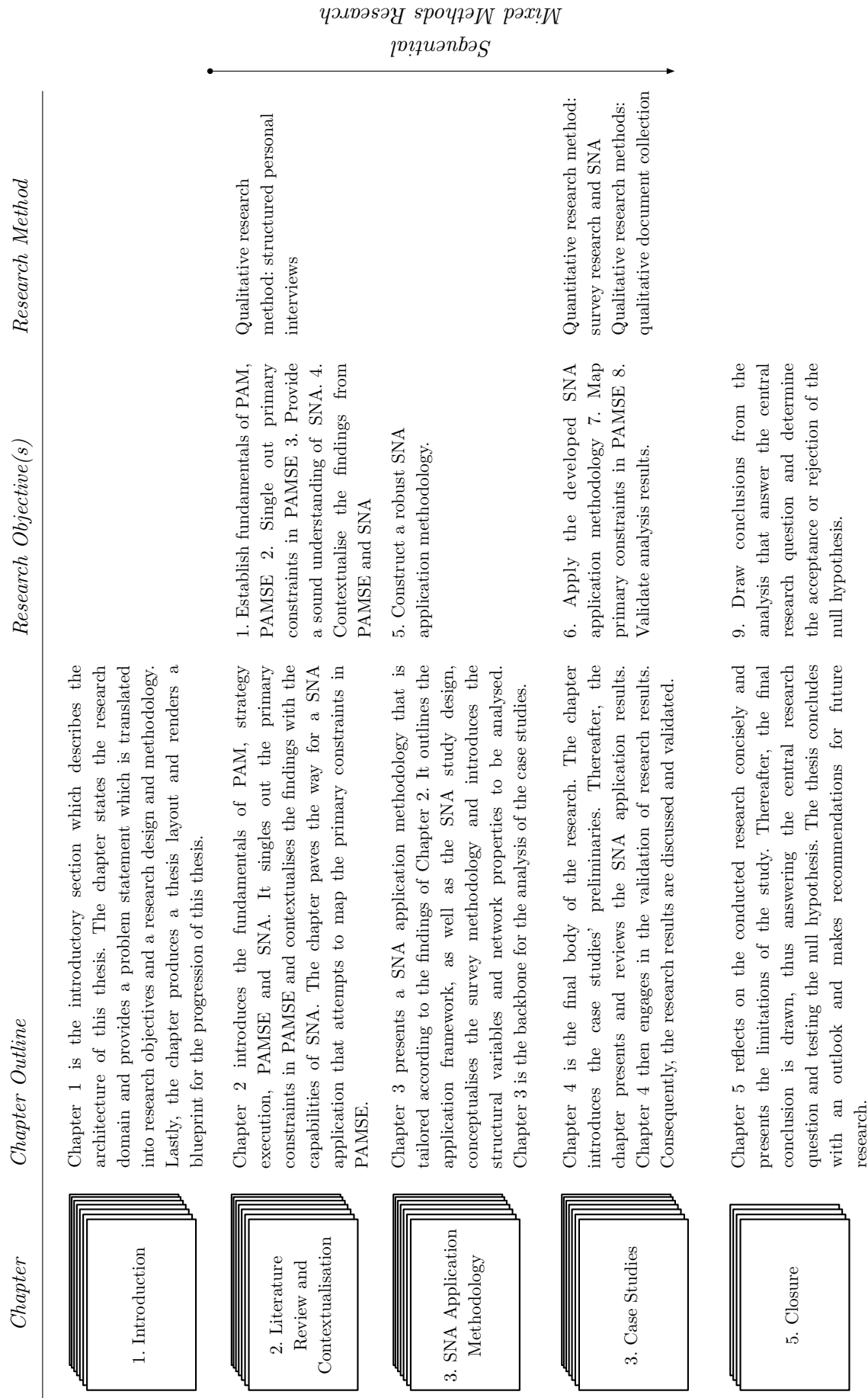


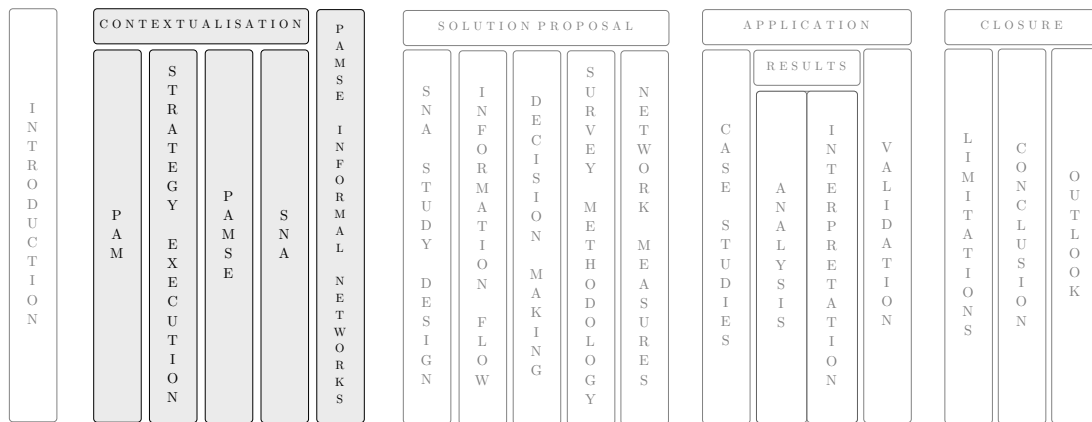
Figure 1.7: Thesis blueprint.

Chapter 2

Literature Review and Contextualisation of Study

Chapter Aim:

This chapter aims to single out the primary constraints in PAMSE and to contextualise the findings with the capabilities of SNA, in the hopes of showing that the method provides the means to portray problem areas. Chapter 2 paves the way for a SNA application.



Chapter Outcomes:

- Comprehension of PAM and contemporary traits of this field.
- Understanding of strategy and obstacles to its execution.
- Delineation of PAMSE.
- Discovery of the primary constraints in PAMSE.
- Introductory comprehension of SNA and its capabilities to discern problem areas in PAMSE.

2.1 Physical Asset Management

The field of PAM is accompanied by ambiguous terminology. This is essentially because of the synonymical use of the term “asset management”. This term is used by a variety of professions, which leads to much confusion. Mitchell (2007) and Woodhouse (2006) demonstrate that the expression is commonly used in finance, real estate, corporate management, information technology and a host of other areas. Apart from these contexts, the term asset management has increasingly been adopted to describe the holistic management of physical assets over their entire life cycles. This thesis builds upon the latter understanding.

Hastings (2009) states that historically, PAM has not been a well defined activity. This is mainly because educational and professional specialisations have caused the isolation of the disciplines that are involved in the management of physical assets. Woodhouse (2006) states that physical assets have been managed for years, but that contemporarily the scope in the management of these assets has shifted considerably. Traditionally there was a focus on the maintenance of physical assets, but a more holistic approach has been strongly advocated in the past few years. Amadi-Echendu *et al.* (2010a) indicate that since the 1990s an interdisciplinary approach for PAM has been supported. The work by Schuman and Brent (2005) draws on multiple sources that endorse a broadened scope of PAM. Analogous, Amadi-Echendu (2006) refers to a number of key developments, illustrating that good PAM is compelled to adopt an integrated approach. Woodhouse (2006) and Amadi-Echendu (2006) agree that major threats to successful management of physical assets are based on short termism and the silo mentality inherent in traditional and myopic disciplinary paradigms.

Today, PAM clearly exceeds the traditional self contained interpretations. The present rule lies in the provision of an integrated, optimised, whole life cycle and multidisciplinary management of the organisations *mix* of assets.

2.1.1 Assets, Asset Types and Asset Systems

The term “asset” conveys diverse and distinct interpretations. In the PAM literature it becomes evident that different asset types are recognised and that it is understood that they must not be managed in isolation of each other. Chareonsuk and Chansa-ngavej (2010) emphasise that despite the common, tangible assets, in the form of equipment, machinery and infrastructure of the industrial age, intangible assets are of increasing importance for the value-creation process. It is made clear that intangible assets are ubiquitous across all functions and levels of organisations.

Amadi-Echendu (2006) points out that the advent of the innovation, knowledge and learning economy paradigm also demands a shift towards the broader asset management. Stewart *et al.* (2003) clarify that the management of physical assets is vitally supported by six main elements. These elements are: processes, practices, information systems, data and knowledge, commercial tactics and organisational and peoples' issues.

In comparison to the views expressed in publications, the PAM standard PAS 55 depicts different asset types that have to be managed holistically. PAS 55 identifies five broad asset categories that have to be managed integrally, these are: human assets, physical assets, information assets, intangible assets and financial assets. At present, an organisations assets are viewed as mutually complementary asset combinations. In accordance with PAS 55 this thesis introduces the term *asset system*. According to BSi (2008a, p.2) an asset system is a “set of assets that interact and/or are interrelated so as to deliver a required business function or service”. PAS 55 acknowledges that the management of physical assets and asset systems is inextricably linked to other asset categories. Figure 2.1 shows the interplay of the five broad asset categories as identified by PAS 55.

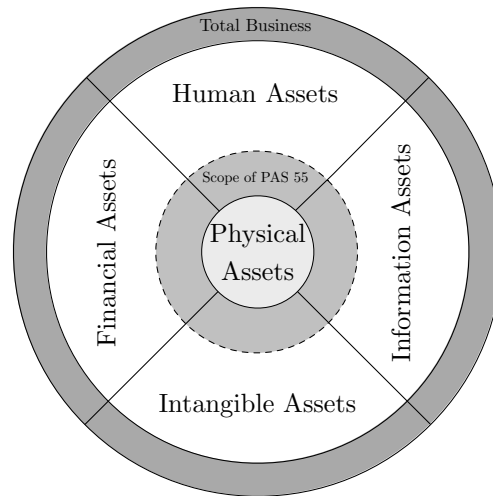


Figure 2.1: Five broad asset categories.

Adapted from PAS 55.

Definition of Asset

PAS 55 adopts a definition for “asset”, that heavily emphasises physical assets and neglects other asset categories that can form part of an asset system. It is contended, that the definition by Nonaka *et al.* (2000) has great advantage because it is not

biased towards a certain asset type. When referring to very different asset types, this definition is most appropriate. In this thesis a *physical asset* shall be defined according to BSi (2008a, p.2) as “plant, machinery, property, buildings, vehicles and other items that have a distinct value to the organisation”. For *asset* in general, the definition by Nonaka *et al.* (2000, p.20) is referred to, which states that asset(s) are “firm-specific resources that are indispensable to create values for the firm”.

2.1.2 Physical Asset Management: Definition

The definition of PAM has undergone a paradigm shift towards a broader view with stronger focus on organisational integration. Traditional definitions shy away from an integral approach that joins bordering disciplines. More recent definitions acknowledge the broader conceptualisation and organisational integration tendency of PAM. The literature provides a great variety of definitions for PAM¹. As one of the pioneers, Mitchell and Carlson (2001) characterise PAM as a strategic, integrated set of comprehensive processes to gain the greatest lifetime effectiveness, utilisation and return from physical assets. In response to industry’s demand for a standard of PAM, the Public Available Specification 55 (PAS 55) has been published by the BSi. PAS 55 reflects the international consensus on PAM, expressing the interdisciplinary approach and integrated perspective of the concept. This thesis adopts the definition presented in BSi (2008a, p.2). Accordingly, PAM is defined as the

systematic and coordinated activities and practices through which an organisation optimally and sustainably manages its physical assets and asset systems, their associated performance, risks and expenditures over their whole life cycles for the purpose of achieving its organisational strategic plan.

There is inconsistent use of vocabulary for purposes of PAM. While terms like “asset management”, “total asset management”, “engineering asset management” and “physical asset optimisation” coexist throughout the literature, this thesis chooses to make consistent use of the term PAM. All definitions from have been harmonised with this decision.

2.1.3 Organisational Generality

Woodhouse (2006) highlights that organisations which rely heavily on their physical assets realised that the functioning of traditional silos and separation fails to exploit

¹Exemplary, see McElroy (1999), Vanier *et al.* (2001), Schuman and Brent (2005), Woodhouse (2006), Amadi-Echendu (2006), Amadi-Echendu *et al.* (2010b) and Stewart *et al.* (2003).

major opportunities. Hastings (2009) illustrates that habits of educational and professional specialisations bring about a silo effect in the areas that are involved in PAM. However, the distinct skill set of engineering, finance and accounting, information technology or senior management have to be incorporated collectively to pay heed to PAM, and thus comply with the long term planning horizon of the organisation. This view is shared by Mitchell (2007) and (Kellick, 2010). The authors point out that despite engineering skills, PAM also encompasses competencies as strategic management, human resource and financial management, as it rests upon multidisciplinary competencies. Nevertheless, Hastings (2009) offers criticism that an understanding of the activities concerned with planning, financing, operating and maintaining physical assets, against the background of strategic plans rarely exists.

Stewart *et al.* (2003) state that PAM integrates different organisational and management levels into one focus, thereby striving for maximum asset performance. PAM is a management paradigm that crosses all levels of an organisation, rather than a set of disjointed efforts of improvement. McElroy (1999) argues that an PAM framework is made effective by organisational integration and technological support. In the same way, the PAM framework presented by Stewart *et al.* (2003) is aimed at the provision of a coordinated agency-wide perspective on asset management. The authors recognise that the management of physical assets is supported by processes, practices, information systems, data and knowledge, commercial tactics and organisational and peoples' issues. This view is again reflected by Amadi-Echendu (2006), who joins different schools of thought. The author adopts a lifecycle approach for physical assets against a backdrop of the organisation's value chain and the demands for a holistic approach. This crosses traditional disciplinary boundaries towards an integrated perspective. Amadi-Echendu *et al.* (2010*b*) argue that the interdisciplinary approach of PAM implies a multi-faceted skill set which is needed to address the vexed issues of the PAM field. According to Amadi-Echendu *et al.* (2010*b*) five key characteristics of a broader conceptualisation of PAM are highlighted by the literature, they are shown in Table 2.1.

The belief in the imperativeness of interdependencies between asset categories and between organisational functions is shared in the literature and formalised in PAS 55. Amadi-Echendu *et al.* (2010*b*) see the shift in the PAM paradigm to be an unwritten consensus between practitioners and academics alike. It is echoed that physical assets have to be managed in an agency-wide context and can not be addressed in isolation of the professions and activities that PAM departs from. PAM crosses organisational and disciplinary boundaries.

Table 2.1: Key characteristics of PAM.

| | |
|------------------------------|---|
| 1. Spatial generality | PAM extends across all types of assets, including human resources, in any industry. |
| 2. Time generality | PAM extends over time to include short term and long term aspects of physical assets. |
| 3. Measurement generality | Real and financial measurement dimensions: measurement data includes measures of economic value, social attributes as well as physical attributes of assets. |
| 4. Statistical generality | Risk and other higher moment estimates of measures are important in asset management, as well as the basic, first moment return measure of asset performance. |
| 5. Organisational generality | PAM takes place at all levels of the organisation, from direct contact with the asset, to the strategic interactions that take place in the boardroom. |

Adapted from Amadi-Echendu et al. (2010b).

Figure 2.2 exemplifies the organisational integration of asset management in correspondence to the hierarchical structure of a fictitious organisation. The arrow indicates that asset management may be further integrated across businesses, creating alignment on a corporate level. The illustration depicts the cross-functional strategic alignment of PAM, as understood by this thesis, and aims to provide guidance to the reader.

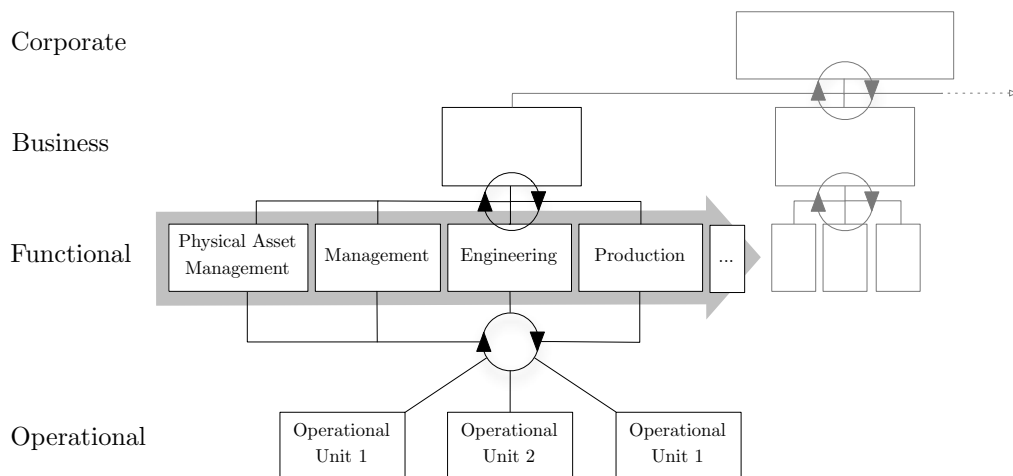


Figure 2.2: Organisational integration of PAM.

2.1.4 Human and Strategic Dimension

Amadi-Echendu *et al.* (2010*b*) and Woodhouse (2006) highlight the broader strategic and human dimensions in the field of PAM. Hastings (2009) points out that business functions such as sales, operations, finance and human resource management may be clearly present in the business structure. PAM in turn may decay as a “grey area” between strategic and operational activities. Due to spanning across different functions, PAM becomes a matrix activity that is more difficult to grasp. Additionally, PAM places great focus on the strategic alignment with the long-term organisational objectives. Because its concern exceeds the traditional purview, chances are that PAM could perish as a fad and not receive sufficient attention.

Woodhouse (2006) argues that success in PAM is achieved through the clear alignment of top-down managerial direction and bottom-up delivery capabilities, leveraging the enablers of human factors an important component of success. Amadi-Echendu *et al.* (2010*b*) state similar expectations. Despite the challenges of technological advances, the authors expect the main difficulties to most likely arise from the bias towards traditional conceptions, organisational settings and associated cognitive dispensations. Tsang (2002) highlights the human dimension as a key success factors for the management of physical assets. The author finds that human factors and information flow permeate the strategic dimensions of maintenance management. The author argues that an understanding of behaviour at work and parameters of group effectiveness will yield better organisational design, fostering employee commitment and chances of success in change programs. Stewart *et al.* (2003) outline six elements that are central to an asset intensive organisations value chain, amongst these the authors mention people. Woodhouse (2006) stresses the fact that tools and techniques merely deliver assistance, but ultimately it is people that “make things happen” and are accountable for the desired realisations. With the background of the cross-functional character of asset management, the presented expectations in PAM publications get fortified by Cross *et al.* (2002*a*). The authors state that practical experience and scholarly research indicate the difficulty in achieving collaboration of people with different expertise and background. Amadi-Echendu *et al.* (2010*b*, p.7) conclude that the human dimension of PAM needs to be dealt with competently, both in terms of training and of managing processes, in order to ensure effectiveness of PAM: “It is the human factor that is the weak link in the chain”.

The literature consistently emphasises the importance of the human and strategic dimension. The present approach of PAM deems the human dimension and strategic alignment to be essential requisites of successful PAM. Amadi-Echendu *et al.* (2010*b*)

derive three major implications that concisely reflect on the current challenges for PAM, they are shown in Table 2.2.

Table 2.2: Major implications for PAM.

-
-
1. PAM is multidisciplinary since it requires the input of skills from virtually any discipline, such as engineering, information technology, economics and management.
 2. Decisions in PAM extend from strategic to operational and tactical aspects.
 3. The human dimension of PAM requires the use of qualitative and more traditional quantitative modes of analysis.
-
-

Adapted from Amadi-Echendu et al. (2010b).

2.1.5 Public Available Specification 55

The Public Available Specification, in short PAS 55, is a standard for the management of physical assets and related asset systems. Initially published in 2004, the standard has been reviewed and was updated in 2008. PAS 55 recognises different, intersecting categories of organisational assets but is particularly focussed upon the management of physical assets. It considers other asset categories solely if those have a direct impact on the management of physical assets. The central role of physical assets in the specification is also illustrated by Figure 2.1. The standard states that it is applicable to the three main categories of organisations shown in Table 2.3. Organisations that are in accordance with one or more of these characterisations are frequently referred to as *asset-centric* organisations.

The standard's development has been led by the Institute of Asset Management (IAM) collaboration with the BSi and with the assistance of a number of co-operating companies and individuals². PAS 55 is subdivided and published in two parts. The first part, "PAS 55-1: Specification for the optimised management of physical assets" provides recommendations for establishing, documenting, implementing, maintaining and continually improving an Asset Management System (AMS), see BSi (2008a). Part two, "PAS 55-2: Guidelines for the application of PAS 55-1" comprises guidelines for the application of PAS 55-1, see BSi (2008b). Hereinafter, PAS 55 is referred to as a specification, rather than the standard's individual publications. It may be noted that PAS 55 is a primary contributor to the development of the emerging International Organisation for Standardisation (ISO) 55000 specification. PAS 55-2

²A listing of the co-operating companies is given in PAS 55-1.

explicitly points out that it does not provide mandatory approaches, methods or tools for the implementation of the requirements as stated by PAS 55-1. Its scope is limited to aiding the understanding and implementation as a framework. As put by Hastings (2009), PAS 55 provides a general framework but no details of the various techniques and practices of PAM are included.

Table 2.3: PAS 55 field of application.

-
-
1. Any physical asset intensive business, where significant expenditure, resources, performance dependency and/or risks are associated with the management of physical assets.
 2. Any organisation that has, or intends to manage or invest in, a significant portfolio of physical assets, or where the performance of asset systems and the management of physical assets are central to the effective achievement of business objectives.
 3. Organisations where there is a business or public accountability requirement to demonstrate best value in the safe management of physical assets and provision of associated services.
-
-

Adapted from PAS 55.

This thesis refers to the AMS as a corner post for its theoretical positioning. In the following sections, it will be shown that the AMS can be used to understand the strategic management process in PAM. The primary purpose of an AMS is to support the organisational strategic plan and to provide the “line of sight” between organisational strategic direction and the every day management of assets. The AMS means to align the “top down” organisational aspirations with the “bottom up” realities and opportunities of the asset portfolio. PAS 55 states that an AMS is vital to master the complexity and diversity of assets in consideration of the organisational objectives. The framework fosters a better understanding of the research domain in this thesis. Figure 2.3 gives a basic overview of the AMS’s structure in the context of the organisation’s strategic plan and its stakeholders. In line with PAS 55, an AMS is defined as the

organisation’s physical asset management policy, physical asset management strategy, physical asset management objectives, physical asset management plan(s) and the activities, processes and organizational structures necessary for their development, implementation and continual improvement.

Amadi-Echendu (2006) shows that next to PAS 55 other manuals for PAM exist. Multiple specifications and numerous frameworks that are developed internally by

asset-centric companies demonstrate the need for a model that consolidates the consensus in the field. The PAS 55 standard is undoubtedly the most widely accepted framework. The standard itself states that it reflects the increasing international consensus in the requirements of PAM. The timeliness of PAS 55, as well as its wide acceptance in industry, is why this thesis pays considerable attention to the specification and bases the fundamental understandings of PAM upon it.

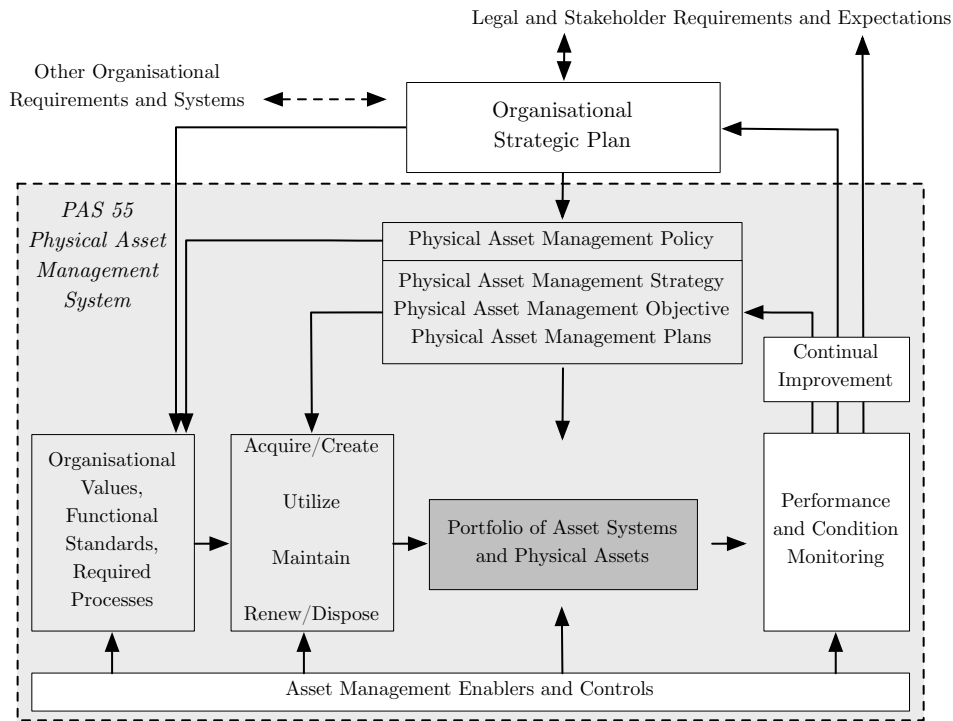


Figure 2.3: PAS 55 AMS.

Adapted from PAS 55.

2.2 Strategy Execution

Strategy is an abstract and elusive concept which makes it difficult to elicit its core. The research community provides various definitions and views that encapsulate the concept of strategy. Kaplan and Norton (2001, p.10) say, there are “as many ways of describing a strategy as there are strategy theorists and methodologies”. Following Nag *et al.* (2007), it is commonly asserted that the field of strategic management is fragmented and lacks a coherent identity. Because there are many different views on strategy, it is best to only refer to a handful of strategy authorities and present only some selective views.

Robbins and Coulter (2012) show that strategies exist on different organisational levels. Correspondingly, Figure 2.4 illustrates that strategies involve the participative development of goals and strategies for different levels inside the organisation. As shown in Figure 2.2, PAM represents one such branching area in the organisation.

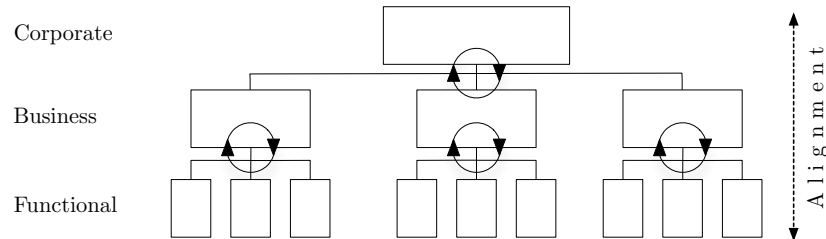


Figure 2.4: Level of organisational strategy.

Adapted from Robbins and Coulter (2012).

The work by Mintzberg (1987) and Porter (1996) illustrate that strategy is of a complex and multi-faceted nature that can hardly be grasped by a single definition. Mintzberg (1987) argues that the field of strategic management cannot afford to rely on a single definition of strategy. In contrast to other publications in strategic management, both authors do not attempt to fit the nature of strategy into a single defining sentence. Mintzberg (1987) describes strategy with five particular definitions, as a plan, pattern, position, perspective and ploy. At the heart of “what is strategy?” written by Porter (1996), lie the three principles. Firstly, strategy is the creation of a unique and valuable position, involving a different set of activities. Secondly, strategy requires making trade-offs in competing and choosing what not to do. Lastly, strategy involves the creation of a “fit” in the company’s activities. Kaplan and Norton (2001) picture strategy as a route on which executives continuously manoeuvre the company through the competitive environment. Pearce and Robinson (2009) form the symbol of a strategy as a company’s “game plan”. To a certain extent, the definition by Thompson and Strickland (1987) correlate with some of the views that permeate the literature. This particular definition shows that strategy is present on different levels of the organisation and encompasses determined actions to achieve an organisation’s objectives and desired positioning. Furthermore, the definition points out that success must be sustained and therewith implies the continuous character of strategy. Strategy has many faces. Yet, for the purpose of this thesis *strategy* shall be defined according to Thompson and Strickland (1987):

“Strategy is the blueprint of all entrepreneurial, competitive and functional area actions to be taken pursuing organisational objectives and positioning an organisation for sustained success.”

Similar to the concept of strategy, the domain of strategic management is also affected by a variety of concepts. For the purposes of this thesis, *strategic management* is defined as the collection of activities that develop and materialise the organisation's strategies. According to Robbins and Coulter (2012) the strategic management process involves six steps. Steps one to four encompass the strategic planning and the remaining two steps are comprised of strategy implementation and evaluation. The process is shown in Figure 2.5. In line with the scope of this thesis and in the context of PAM, the properties of step five are of foremost concern.

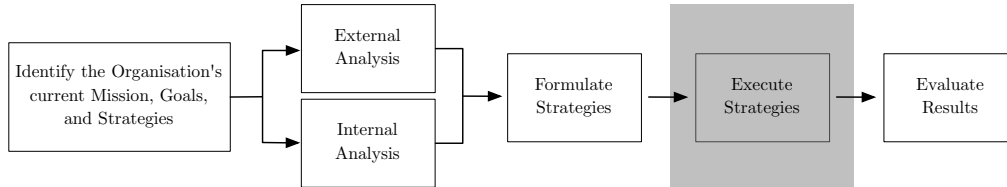


Figure 2.5: Strategic management process.

Adapted from Robbins and Coulter (2012).

2.2.1 Definition

The essentials of strategy and strategic management have been concisely subsumed. In this section the concept of “strategy execution” is discussed. After a workable definition is derived from texts in strategic management, some contemporary research developments are outlined. As is common practice in the literature, no distinction between strategy implementation and execution is drawn and the terms are used synonymously.

Strategy execution is an integral part of the strategic management process, this is presented in Figure 2.5. After planning and formulating a strategy it has to be put into action to take effect. The Oxford English Dictionary (OED) defines “execution” as the action of carrying a plan, purpose, command, task, or course of action into effect, see OED (2012*b*). Because strategy is an ever changing pursuit, its execution becomes an ongoing process, rather than an once-off event. Neilson *et al.* (2008) express an organisation's execution capabilities as the ability to effectively translate important strategic and operational decisions into action. Blahová and Knápková (2011) describe strategy execution as a process or logical set of connected activities that enables an organisation to “take a strategy and make it work”. Kaplan and Norton (2004) agree with this view, the authors state that the execution of strategy is eventually achieved through the execution of initiatives. Action programs or strategic initiatives are required to achieve the targets for each measure that has been

specified during the planning phase. A strategy has to be translated into a strategic plan that contains measurable objectives and targets which can be achieved through strategic initiatives. To “make strategy work”, despite the transformation of plans into actions, further determinants require consideration. Kaplan and Norton (2001) present five key principles for achieving strategic focus and alignment. Kaplan and Norton (2008) also presented an earlier study that involved six strategy execution processes. The work by Pedersen (2008) links to the principles stated in Kaplan and Norton (2001, 2008). Strategy execution encompasses the *translation* of strategic aspirations into initiatives as well as the *resource allocation* and *coordination* of responsibilities and accountabilities. Furthermore, key personnel have to be made familiar with the strategic endeavours and the plan of action through *communication*. In addition, strategy implementation is a reactive process and may demand *adaptation* in time. The corresponding views are summarised in Table 2.4.

Although a variety of publications deliver growing insight into the topic, Blahová and Knápková (2011) criticise frameworks for strategy execution as comparatively fragmented and idiosyncratic. For the purposes of this thesis, the definition of strategy execution is aligned to the many characteristics that pervade the literature:

Strategy execution is the process of translating strategy aspirations into workable actions and managing strategic initiatives through the allocation of resources, coordination of responsibilities and accountabilities, while continuously reviewing, adapting and communicating this very process.

Long Unattended - Yet Imperative

Kaplan and Norton (2001) point out that for long, the properties of strategy execution have been left unattended by the research community. Hrebiniak (2005, 2006) concurs with this view, and explains that for a long time, the management literature has predominantly focused on parading new ideas on strategy planning and formulation, but has sorely neglected execution. Rosenzweig (2007) quotes the former head of Honeywell, Larry Bossidy:

“Execution is the great unaddressed issue in the business world today. Its absence is the single biggest obstacle to success and the cause of the disappointments that are mistakenly attributed to other causes. No strategy can deliver result unless it’s converted into specific actions - and those actions are the stuff of execution.”

Table 2.4: Key principles of strategy execution.

| | | |
|--|--|---|
| Translation: | Translate the strategy. Express the strategy in operational terms. | Process of converting the ideas, visions and aspirations of strategy into workable plans and metrics. |
| Resource Allocation: | Create alignment between the organisation and the strategy. | Linking the strategy to the resources required to execute it. |
| Communication: | Communicate the strategy. | Ensuring that all key employees are aware of and understand the “what”, “why”, “how”, “when” and “who” of the strategy. |
| Coordination: | Get everyone involved in making strategy. | Passing on both responsibility and accountability to key personnel for a specific action or goal. |
| Adaptation: | Make strategy an ongoing process, not a one-off event. Review and update the strategy. | Monitoring process of strategy implementation and making adjustments to the strategy. |
| <i>Adapted from Kaplan and Norton (2001, 2008), Pedersen (2008).</i> | | |

In contrast to the lack of conventional practices of how to execute strategy, theories and advice concerning requisites of good strategy planning and formulation abound in the management literature. It seems, however, as if the interest in strategy execution has gained momentum over the last years. Textbooks by Hrebiniak (2005), Thompson *et al.* (2005) and Kaplan and Norton (2008) as well as multiple article publications³, show an emerging interest in this field. Kaplan and Norton (2008) show that the consultancy “Monitor” report strategy execution as the first priority in the years 2006 and 2007. Although theorists, consultants and business press have spent decades focussing on devising quality strategies, Kaplan and Norton (2001) point out that sophisticated investigations acknowledge that the ability to execute strategy is more important than its quality. Research by Mankins and Steele (2005) and Neilson *et al.* (2008) suggest that strategic performance losses are widely attributable to the aspects of execution. Neilson *et al.* (2008) stress that successful execution is imperative to sustaining success. In the words of Hrebiniak (2006, p.12): “Without effective implementation, no business strategy can succeed.”

³For example see Zook and Allen (2001), Higgins (2005), Mankins and Steele (2005), Hrebiniak (2006), Kaplan and Norton (2001, 2005), Neilson *et al.* (2008) and Martin (2010).

Making Strategy Work is More Difficult than Making Strategy

Neilson *et al.* (2008) state that a brilliant strategy can elevate a company into a competitive position. However, it is emphasised that only the ability to deliver the intention of the strategy sustains an advantageous position. Robbins and Coulter (2012) affirm that even the best strategies can fail if management do not implement or evaluate them properly. Kaplan and Norton (2008) look at multiple surveys which conclude that 60 to 80% of companies fail to realise their strategic targets. According to Zook and Allen (2001) as many as 90% of companies fail to realise their strategic ambitions. Charan and Colvin (1999) show that 73% of failures at executive level are primarily caused, not by flawed strategic thinking, but by the failure to execute. Poor strategy execution appears to be a common dilemma. The statistics assembled in Table 2.5 accentuate the difficulties in strategic and execution performance.

Table 2.5: Statistics regarding strategy execution.

| | | |
|------------|--|---------------------------|
| 95% | Of a company's employees are unaware of, or do not understand, its strategy. | Kaplan and Norton (2005) |
| 90% | Of all companies fail to realise their strategic ambitions. | Zook and Allen (2001) |
| 73% | Of employees do not have access to the organisation's strategic plans. | Axson (1999) |
| 70% | Of CEO failures are primarily caused, not by flawed strategic thinking, but by the failure to execute. | Charan and Colvin (1999) |
| 63% | Of strategies' financial performance is realised, on average. | Mankins and Steele (2005) |
| 60% to 80% | of companies fail to realise their strategic targets. | Kaplan and Norton (2008) |
| 60% | Of organisations do not link their budgets to strategic priorities. | Kaplan and Norton (2005) |
| 58% | Of managers do not have access to the organisation's strategic plans. | Axson (1999) |

Hrebiniak (2006) makes the point, that it is typically not the "planning" which is accountable to poor performance but the "doing". The lack in execution know-how and the inability to confront obstacles of execution, is the downfall of many sound

plans. Kaplan and Norton (2008) rely on the words of Tony Hayward, former CEO of British Petroleum: “Our problem is not about the strategy itself, but about our execution of it.” This is an ironic statement in the light of the events surrounding the oil rig “Deepwater Horizon”, that caused the largest offshore oil spill in the history of the United States of America in the year 2010. Kaplan and Norton (2001) point out that highly productive organisations implement strategy exceptionally well. In fact, they typically place more emphasis on execution than on strategy formulation. Hrebiniak (2006) believes that while formulating strategy is difficult, making strategy work and executing it throughout the organisation, is even more difficult. The above findings and the quest for successful execution draws the attention to the causes of failure: the obstacles to strategy execution.

2.2.2 Constraints

A number of researchers specifically investigated the properties of failure and success in strategy execution. This thesis attempts to consolidate the findings from previous research and presents constraints in front of the background of the respective key principles of strategy execution. Although the study places its focus on concerns that are primary constraints, it is cognisant for the problems areas in their periphery.

Inadequate Translation

Implementation begins with the strategy itself. Although, the strategy itself does not lead to immediate action. Larry Bossidy, quoted by Rosenzweig (2007) points out that “no strategy can deliver results unless it’s converted into specific actions.” Actions are to be derived from a formulated strategy. Beer and Eisenstat (2000) and Hrebiniak (2006) explain that a poor, vague or conflicting strategy impedes implementation efforts and thus presents an obstacle. Pedersen (2008) argues that the translation makes strategy understandable and workable. Strategic aspirations and visions are ambiguous and require to be expressed in organisational contexts and actions. The author says that the purpose of strategy translation is to reduce uncertainty and incomprehensibility. Kaplan and Norton (2001) formulate key principles in achieving strategic focus and alignment, see Table 2.4. Amongst others, the strategy has to be expressed in operational terms. Flawed strategy translation may result in a lack of strategic alignment. Mankins and Steele (2005, p.126) explain, that if strategy is poorly translated “lower levels in the organization don’t know what they need to do, when they need to do it, or what resources will be required to deliver the performance senior management expects. Consequently, the expected results never materialize.”

Hrebiniak (2005) outlines that in strategy execution, the strategy itself has to be clear and focused. It is essential to logically translate the strategy into objectives and metrics. The logical manner of translating is imperative. Objectives and measurements need to be consistent to anticipate competing views of execution results. Good strategy translation is pivotal to a clear and understandable strategy execution process.

Inadequate Resource Allocation

Strategy execution necessitates resources. Kaplan and Norton (2005) illustrate that budgeting is often disconnected from strategy. As many as 60% of organisations do not link their financial budgets to strategic priorities. The authors pinpoints further that the people who have to carry out the strategy have to be motivated and trained to do so. Al-Laham (1997) shares concerns about restrictions in resources. The author names insufficient planning of actions and time constraints as problem areas. Insufficient or indecisive resource allocation may restrict the execution process. Apart from this, Beer and Eisenstat (2000, p.36) add that a lack of cross-functional reviews of initiatives may result in a situation where too many projects chase too few resources.

Inadequate Adaptation

Strategy is reactive to the environment and is thus of an ever changing nature. Kaplan and Norton (2005), therefore, recommend making strategy an ongoing process, rather than an one-off event. Blahová and Knápková (2011) state that dynamism is required in order to respond to unanticipated events. Strategy execution is an ongoing process, it needs to be evaluated and pass multiple iterations in order to make adjustments. Al-Laham (1997) looks at missing information- and control systems to monitor progress. This is echoed by Hrebiniak (2005); the author criticises the required controls and feedback of the adaptation process for often not working. Further, Al-Laham (1997) argues that for too long, planning horizons in connection with swift environmental changes, have made the execution plans obsolete.

Inadequate Coordination

Thompson *et al.* (2005, p.256) emphasise that strategy execution depends on “doing a good job of working with and through others”. The studies by Hrebiniak (2006) indicate that strategy implementation heavily relies on employee support for the execution plan. This is chiefly, because executing initiatives often requires certain individuals to perform or change in some or other way. It demands influential people, with the ability to lead change, to drive others into purposeful action. In addition,

Kaplan and Norton (2005) suggest that it is vital to select suitable people for figuring in the execution process. Beer and Eisenstat (2000) also highlight inadequate down-the-line leadership as an obstacle. This is affirmed by Kaplan and Norton (2001), the authors find that without effective leadership and active, personal involvement from organisations' executives, no strategy will ever succeed. Hrebiniak (2006, p.18) says: "Trying to execute a strategy that conflicts with the prevailing power structure clearly is doomed to failure." Hence, working against the power structure or without support from employees poses an obstacle to successful strategy execution. Influential key personnel is indispensable to drive the execution process.

Hrebiniak (2005) suggests that it is vital that both, responsibilities and accountabilities are clearly defined and assigned to the key people in the strategy implementation process. This point is repeatedly highlighted by Neilson *et al.* (2008). According to this research, the fact that everyone has a good idea of the decisions and actions for which he or she is responsible is deemed as the prime-prerequisite to successful execution. When responsibilities and accountabilities are unclear, decision rights blur and no one person can be clearly held accountable. Consequently decisions are elevated up the organisational hierarchy, get vetted by various parties or stalled. This hampers decision making processes and imposes significant obstacles to the execution of strategic initiatives. Mankins and Steele (2005) add that if nobody is held responsible for shortfalls, cycles of underperformance get repeated, often for many years.

Al-Laham (1997) specifically identifies problem areas at the interfaces of different organisational levels, coupled with uncertainty of where responsibilities lie. Higgins (2005) emphasises that dissemination and integration of execution actions is particularly challenging when it involves cross-functional activities. Hrebiniak (2006) adds that strategies demand cooperation and effective coordination across organisational silos. The author agrees that coordination across organisational units certainly suffers if responsibilities and accountability are unclear. Research by Beer and Eisenstat (2000) reaffirm this view. It is suggested that poor coordination across functions, businesses and borders is a barrier to strategy implementation.

Strategy execution requires a team effort that requires top-level advocates and the support of employees from every organisational level. Ambiguity in responsibilities and accountabilities leads to diluted role definitions and unclear decision rights that obstruct effective strategy execution; especially in cross-functional settings. In the words of Beer and Eisenstat (2000, p.37): successful implementation requires "the right people to work together on the right things in the right way."

Inadequate Communication

Neilson *et al.* (2008) state that execution results from the myriad of day-to-day decisions, made by employees who act according to the information they have available and on the basis of their own self-interest. Communication promotes the strategic direction and actions. As Pedersen (2008, p.29) puts it, communication ensures that all key employees are aware of the “what”, “why”, “how”, “when” and “who” of the strategy.

Hrebiniak (2006) argues that strategy execution involves more people than strategy formulation and that the sheer number of employees to be educated makes vertical and horizontal communication a challenge. Kaplan and Norton (2005) show that 95% of employees are unaware of or do not understand the organisations strategy. Neilson *et al.* (2008) state that the rational decisions by employees are necessarily bound by the information available to them. Their research shows that 61% of individuals in organisations that are strong in execution, agree that field and line employees have the information they need to understand the bottom-line impact of their decisions. In the weaker organisation this figure drops to 28%.

Beer and Eisenstat (2000) and Blahová and Knápková (2011) draw the attention to poor vertical communication as a barrier to strategic alignment. On the one hand the authors express the view that, if information sharing is lacking, the top level management work with information that pass several rungs of the hierarchy and thus get diluted along the way. On the other hand they criticise the absent willingness of senior management to engage open candid problem discussions. Neilson *et al.* (2008) demonstrate that senior management can serve a powerful function in promulgating best practices. Although, they can only take on this coordinating role with accurate intelligence.

Information exchange also plays an important role in coordinating across silos and bridging functions. According to Hrebiniak (2006) obstacles to strategy execution originate from poor and inadequate information sharing among individuals or units that are responsible for strategy execution. Neilson *et al.* (2008) explain that if information does not flow horizontally across different parts of the company, units behave like silos, forfeiting economies of scale and the transfer of best practices.

Al-Laham (1997) points at resistance and acceptance problems as impediments to strategy execution. Strategy execution involves change processes, new initiatives, tasks and responsibilities that rely on the participation of employees. Hrebiniak (2006) coincides, the author points out that an organisation’s inability to manage

change effectively, and overcome resistance to change, places barriers to the execution. According to Vahs and Leiser (2004), between 50 and 80% of change processes do not achieve their aims. Oltmanns and Nemeyer (2010) find that communication allows to sustainably influence these change processes. Thus, communication can be a remedy for change processes that are at risk or which could ultimately jeopardise execution efforts.

Inadequate information exchange significantly obstructs effective strategy execution. The literature demonstrated several cases. The shortage of information may impede good decision making, which may lead background information and an appreciation for strategy and strategic activities being missed. Resistance and inadequate information sharing hampers integration and collaboration across organisational boundaries. However, information sharing and communication offer to counter these obstacles. Kaplan and Norton (2005, p.77) say: “Effective communication to employees about strategy, targets, and initiatives is vital if employees are to contribute to the strategy.”

Further Matters

Along with the constraints that are possibly linked to either of the key issues, the literature provides a number of other factors that negatively effect strategy execution. Hrebiniak (2006) suggests that managers sorely need a logical model to guide implementation. Further, Hrebiniak (2006) and Blahová and Knápková (2011) add that the successful implementation of strategy is more time consuming than its formulation. This is a challenge for managers as they must “be on the ball” and not lose focus. Further, Neilson *et al.* (2008) and Hrebiniak (2006) mention missing motivators or incentives as dampening to execution efforts. Neilson *et al.* (2008) explain that commonly, organisations engage in measures to modify the organisational structure. Although, it is found that structural changes merely deliver short-term results but do not address the root causes of strategy execution dysfunction. They are in fact the least effective in the long-term. The findings are supported by Beer *et al.* (1990), they find that good intentions embodied in a new structure, were not sufficient to change behaviour.

2.2.3 Primary Constraints

The previous section lists a number of constraints in the successful execution of a strategy. Some of the constraints carry more significance than others. This thesis chooses to focus upon the constraints that are deemed to have paramount impact on execution efforts and thus stand out as the *primary constraints*. In the following

section, the primary constraints are extracted from the bulk of obstacles to successful strategy execution.

The literature review implies that the attention of researchers is particularly drawn towards the domains of *coordination* and *communication*. The research by Mankins and Steele (2005) and Neilson *et al.* (2008) are rare examples of in depth investigations into the properties of strategy execution. The authors investigate causes for shortfalls in transforming strategy into performance and scrutinise the properties of successful strategy execution, respectively. The works shed light on the dominance of certain problem areas in strategy execution. They provide a valuable close up look at different problem areas.

The work by Neilson *et al.* (2008) may provide the most extensive and exhaustive⁴ research in the field. Their research lead to the identification of four “building blocks” that influence strategy execution most, these are; *designing information flow*, *clarifying decision rights*, *aligning motivators* and *making changes to structure*. The authors make it clear that organisations have the habit to immediately initiate restructuring measures in efforts to improve execution performance but find that structural measures are not effective in the long term. The root causes of improved strategy execution are to be found somewhere else. Their research suggests that actions regarding decision rights and flow of information are far more promising. In fact, they are about twice as effective compared to improvements made by the other two building blocks. The building blocks are illustrated in Figure 2.6.

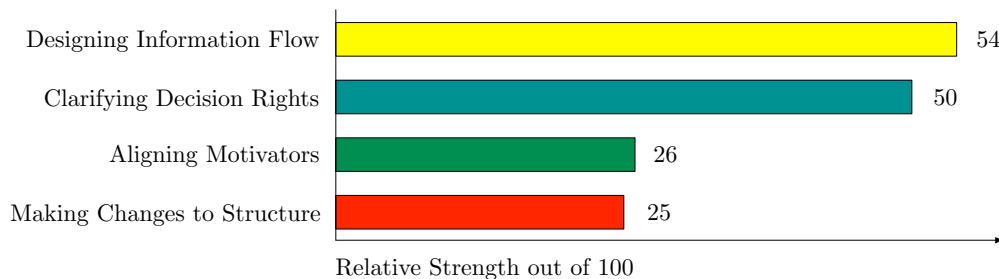


Figure 2.6: Building blocks of successful strategy execution.

Adapted from Neilson et al. (2008).

The researchers consequently associated 17 traits of successful strategy execution to the building blocks. The traits of effective execution were ranked based on 26,743 responses from the years of empirical research. The complete ranking is

⁴According to Neilson *et al.* (2008, p.61) the “building blocks” of successful strategy execution were derived from research involving more than 125,000 data profiles representing more than 1,000 companies, government agencies and non-profits in over 50 countries.

provided in Appendix A. The first eight traits in the ranking solely refer to decision making and information flows. Based on the ranking of thesis traits, the paramount importance of these building blocks becomes apparent. The top five traits of the ranking are shown in Table 2.6.

Table 2.6: Top five traits of successful strategy execution.

| <i>Rank</i> | <i>Organisational trait</i> | <i>Strength Index (out of 100)</i> |
|-------------|---|--|
| 1. | Everyone has a good idea of the decisions and actions for which he or she is responsible. | 81 |
| 2. | Important information about the competitive environment gets to headquarters quickly. | 68 |
| 3. | Once made, decisions are rarely second-guessed. | 58 |
| 4. | Information flows freely across organisational boundaries. | 58 |
| 5. | Field and line employees usually have the information they need to understand the bottom-line impact of their day-to-day choices. | 55 |

Adapted from Neilson et al. (2008).

The survey by Mankins and Steele (2005) indicates that, on average, strategies deliver only 63% of their potential financial performance and 37% of the performance is lost. The performance gap is accounted to the factors shown in Figure 2.7. Accordingly, 4.1% of financial performance is lost due to blurred accountabilities. The failure to allocate the right resources at the right place and time accounts for 7.5% of lost value. Poor communication, silo mentalities and unclear execution actions may be tracked back to insufficient information exchange between organisational hierarchies as well as across functions. Cumulatively, the factors account for 13,4% of performance loss. The research also looks at inadequate leadership and motivators or performance monitoring, which are factors that are mentioned throughout the literature. The work by Mankins and Steele (2005) clearly illustrates which problem domains demand more attention. Problems in information flows, responsibilities and accountability may have a major share in the 37% average performance loss in strategy execution.

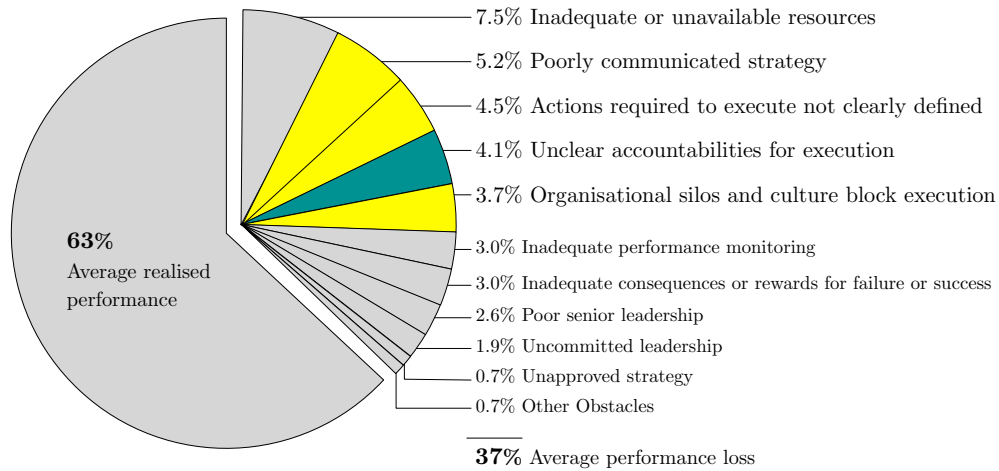


Figure 2.7: Average performance loss in strategy execution.

Adapted from Mankins and Steele (2005).

2.2.4 Interim Result

The literature review conveys an understanding of strategy and portrays the key principles to its execution. Furthermore, it is demonstrated that the strategy execution process can be stifled by a number of constraints. In the literature review a preponderance of problems in communication and coordination surfaced.

The studies by Mankins and Steele (2005) and Neilson *et al.* (2008) deepen the insight into problem areas in strategy execution. Their works mirror the areas of concern that permeate the literature, and reiterate the prevalence of dysfunctional information flows and decision making as salient causes for strategy execution failure. Research by Mankins and Steele (2005) and Neilson *et al.* (2008) highlights the primary constraints in strategy execution. Their works also deliver compelling evidence that information flows, respective communication and good decision making, through clear responsibilities and accountability are the prime requisites to successful strategy execution. Not paying heed to these factors will create insurmountable obstacles to the strategy execution process. *Information flow* and *decision making* are identified as the primary constraints in strategy execution.

The terms “Information flow” and “decision making” are often used without giving sufficient attention to their meaning. The concepts are versatile and could be

understood in many different ways. In order to establish a sound basis for the investigation of these primary constraints, the following two sections elaborate on this notion.

2.2.5 Information Exchange and Communication

Zins (2007) demonstrates that the field of information science is constantly changing and conceptual approaches swiftly evolve and diversify. The article written by Zins (2007) is part of a study which was aimed at exploring the foundations of information science. It maps various conceptual approaches and documents 130 definitions of data, information and knowledge. Instead of conducting a scrupulous conceptual evaluation, it is the aim of this thesis to establish a feasible and sound understanding of information exchange, against the backdrop of scholarly research in this field.

Alavi and Leidner (2001) show that most notably the field of information technology draws a conceptual distinction between data, information and knowledge. Tuomi (1999), mentions that this distinction is also widely adopted in the knowledge management literature. According to Tuomi (1999) and Alavi and Leidner (2001) the commonly accepted view, with minor discrepancies, is that data is raw numbers and facts, that become information as it is processed and combined into meaningful structures. Knowledge is authenticated information which develops when meaningful information is put into a context and can be used to make predictions. This view is generally referred to as the hierarchy of data, information and knowledge. Aamodt and Nygård (1995) and Tuomi (1999) explore the conceptual hierarchy. The authors demonstrate that the evolution of data, information and knowledge conducts is interchangeable. In particular Faucher *et al.* (2008) emphasise the importance of moving away from the concept of hierarchical relationships. For the purpose of this thesis, information is defined according to Faucher *et al.* (2008), who say that information is data that has been processed in some meaningful ways.

Information exchange, or information flow describes the distribution and receiving of information which can be conveyed in different ways. This brings about the definition of communication. Although communication is a vast subject in itself, for the purpose of this thesis, “communication” shall be defined according to the OED (2012a). Accordingly, communication is the “transmission or exchange of information, knowledge, or ideas, by means of speech, writing, mechanical or electronic media.”

The research community draws a conceptual distinction between information and knowledge. Knowledge is seen as a kind of processed or contextualised information; a variety of information. Alavi and Leidner (2001) present various works that point the personal character of knowledge and demonstrate that its transfer involves the cognisance of individuals. The authors state that information flows, drive the knowledge transfer. The transfer of knowledge relies heavily on people's perceptions and is very closely and inextricably related to the transfer of information. This study trusts that there is sufficient evidence that supports an adoption of research findings from knowledge exchange when analysing information exchange.

2.2.6 Decision Making: Responsibility and Accountability

The main concern in this section is to clarify how decisions are made in an organisational context. The aim is not to expand on cognitive decision processes at the individual level. The nature of responsibility and accountability is described by the domain of organisational design. According to Daft (2009), organisational design involves decisions regarding six key elements: work specialisation, departmentalisation, chain of command, span of control, centralisation, decentralisation and formalisation.

Responsibility and accountability fall within the topic of the chain of command. Following Robbins and Coulter (2012), the chain of command is the line of authority stretching from upper to lower organisational levels. Lourens (2006, p.18) explains that authority is the "right to demand compliance by subordinates based on formal position and control over rewards and sanctions". Responsibility emerges when authority is used to assign duties to employees. Lourens (2006, p.18) gives clarity to the term by saying that "responsibility is the assigned obligation of a subordinate to carry out a delegated task or activity". Thus, subordinates can be held accountable for the performance of the tasks assigned to them; this is in effect accountability entails. People may have the responsibility of achieving a particular process or project. The carrying out of a plan of action may be comprised of decisions concerning changes, priorities and possible alternatives for the process or project. The authority to make these decisions is referred to as *decision right*, which is desirably clearly allocated and has at least one "owner". The decision rights' owner is (are) responsible and ideally held accountable for making certain decisions.

2.3 Physical Asset Management Strategy Execution

The character of strategy and the key principles of the execution thereof have been thoroughly explored. Furthermore, the literature study shed light on the primary

constraints in strategy execution. The next objective is to understand how the acquired knowledge can be conveyed in PAM.

In defiance of the crucial role of strategy execution, the topic is disregarded in the field of PAM, as it was based in management science. Despite the fact that most PAM publications do not attempt to thoroughly discuss strategy execution, its imperativeness is recognised by a few. Fogel (2012a) explains that a 75% rated PAM strategy which is executed perfectly can yield fantastic effects, whereas a 100% rated strategy with a 50% execution rate, may fail to achieve a single objective. He says that “it’s all in the execution”. With this in mind the following sections elaborate on the essentials of strategic PAM and foster the comprehension of Physical Asset Management Strategy Execution (PAMSE).

2.3.1 Physical Asset Management Strategy

IAM (2011) explains that the Physical Asset Management Strategy (PAMS) defines what an organisation intends to achieve from its PAM activities. The PAMS contains the PAM objectives and the approach for their achievement. In other words, the PAMS is the context of PAM activities in reaching an organisation’s goals. Instead of implementing disjointed improvement initiatives, the PAMS conducts PAM projects in order to achieve the established PAM objectives.

The PAMS creates a higher level strategic perspective which links the asset portfolio to an agency’s service delivery strategy. Hastings (2009) points out that a PAMS must be responsive to and interact with the business strategy. Amongst other factors, changes in demand for product or service, technological innovations or changes in revenue and cost may influence the business situation and affect the management of physical assets. PAS 55 stresses that the PAM strategy has to assist in the delivery of the organisational strategic plan. Strategic PAM planning enables a focus on the service delivery requirements *of* the physical assets, rather than *on* the physical assets themselves. PAS 55 characterises the function of a PAM strategy by a number of requirements, see Table 2.7. Correspondingly, the asset management strategy transforms the organisations strategic objectives and asset management policy into a high-level, long-term action plan for the asset portfolio(s) that consist of physical assets and asset systems. In line with PAS 55, PAMS is defined as follows:

The physical asset management strategy is the long-term optimised approach to management of the physical assets, derived from, and consistent with, the organisational strategic plan and the physical asset management policy.

Table 2.7: PAS 55 PAMS requirements.

| <i>Reference Section</i> | <i>Requirement</i> |
|--------------------------|---|
| | The strategy shall: |
| PAS 55-1 4.3.1 a) | be derived from, and be consistent with, the physical asset management policy and the organisational strategic plan. |
| PAS 55-1 4.3.1 b) | be consistent with other organisational policies and strategies. |
| PAS 55-1 4.3.1 i) | provide sufficient information, direction and guidance to enable specific physical asset management objectives and physical asset management plan(s) to be produced. |
| PAS 55-1 4.3.1 k) | be communicated to all relevant stakeholders, including contracted service providers, where there is a requirement that these persons are made aware of their physical asset management strategy-related obligations. |

Adapted from PAS 55.

2.3.2 Strategic Management Process

The concept of PAMSE is best understood if framed by a model that depicts the strategic management process for PAM. In search for a suitable model, different viewpoints have been considered. Apart from PAS 55, a number of authors propose concepts that mean to guide PAM and the development and application of a PAM strategy. Amongst others, models stem from the works of Stewart *et al.* (2003), Schuman and Brent (2005), Mitchell (2007) and Hastings (2009). Although the majority of concepts comprise elements that accord with the generic strategic management process presented in Figure 2.5, proposals often fall short of integrity, lack a wider organisational context or are insufficiently discussed. It may however be noted that the concepts developed in Mitchell (2007) seem to be the most comprehensive attempt in the provision of a guiding framework. However, PAS 55's AMS remains the most coherent guideline.

At the most fundamental level, the AMS involves, a planning, formulation, execution and evaluation phase. Although the AMS process does not explicitly specify an analysis phase, the framework shows significant conceptual accordance to the management literature's view on the strategic management process. Figure 2.8 shows that the PAM policy is derived from the organisational strategic plan, providing

guidance for the development of a strategy and objectives. The strategic aims then get converted into concrete plans (Strategy Planning: 1-3). Plans contain specific activities, resources, responsibilities and timescales to achieve the strategy (Strategy Execution: 4). Performance and condition monitoring leads to continuous improvement and feeds back into the planning phases (Evaluate Results: 5). The recognition of PAS 55 as an industry standard and the conceptual correspondence of the AMS, with the strategic management literature, motivates this thesis to rely on the AMS as a model for the strategic PAM process.

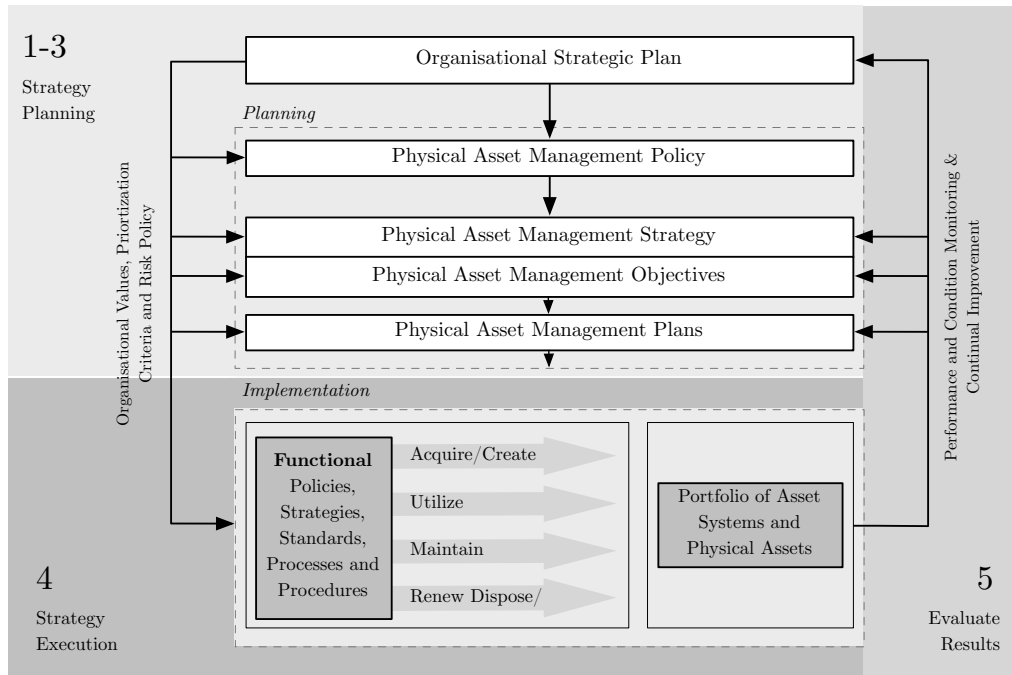


Figure 2.8: AMS planning and implementation elements.

Adapted from PAS 55.

2.3.3 Definition

The following section elaborates on PAMSE and contextualises the concept, using the AMS in order to understand a workable definition of the concept. Arguments are based on the PAS 55 documentation and are corroborated by the knowledge and experience of PAM practitioners.

Newman (2012) explains that the PAM strategy is accompanied by finer components that need to better define how the management of physical assets is engaged. Those finer components are the contents of what PAS 55 denotes as “asset management plans”. BSi (2008a) states that the strategy is achieved through establishing,

documenting and maintaining asset management plans. According to BSi (2008a, p.2) the plans “document specific activities and resources, responsibilities and timescales for implementing the asset management strategy and delivering the asset management objectives.” Hence, the PAM strategy and objectives get converted into more specific plans and actions. Fogel (2012a) agrees with this interpretation. The exceptionally experienced asset management consultant argues that plans come to life only once they are put in place and executed. He says: “Strategy execution is the living embodiment of what you intend to do within the plan.” Fogel (2012a) affirms that after the asset strategy and high-level objectives have been formulated, they get broken down into sub-objectives and sub-initiatives. These get executed in coordination with specific timing and when put together create the required outcomes. Fogel (2012a) further emphasises that the allocation of responsibilities and accountabilities is a crucial task in PAM strategy execution.

The descriptions in PAS 55, as well as the consultation of PAM practitioners, suggests that PAMSE primarily involves a process that transforms the PAM strategy into objectives and more specific strategic initiatives. Initiatives are facilitated by resource allocation and assignment of responsibilities and accountabilities. Ideally, outcomes are continuously monitored, reviewed and fed back into the planning phase. The PAM perspective on strategy execution is thus confidently aligned with the conceptualisation expressed by texts in strategic management. Thus, for the purpose of this thesis PAMSE is defined as

the process of translating the physical asset management strategy aspirations into workable actions and managing strategic initiatives through the allocation of resources, coordination of responsibilities and accountabilities, while continuously reviewing, adapting and communicating this very process.

2.3.4 Primary Constraints

Publications in PAM do not explicitly address strategy execution and associated problem areas. In fact, publications rarely transcend the planning mode of the strategic management process. In contradiction, the management literature and Fogel (2012a) show that good execution is imperative and indispensable to achieving a strategic plan. Especially in PAM, execution is a considerable challenge, as its strategy crosses many functions. Following Higgins (2005), cross-functional endeavours make dissemination and integration of execution actions especially difficult. Nevertheless, a number of indications for good practice in execution are found in various works. An exceptionally extensive collection of barriers to overcome, in gaining successful

PAM is provided by Mitchell (2007). An extract of the most relevant key factors that notably align to other views that emerge in the literature is shown in Table 2.8. At numerous stages throughout his work, Mitchell (2007) points towards the importance of clear roles, responsibilities and accountabilities as well as improved coordination and communication.

Table 2.8: Barriers to successful PAM.

-
-
- Management, organisational control and trust, consistent with stated objectives of empowerment, ownership, responsibility and accountability.
 - Partnership between maintenance and production.
 - Full acceptance, buy-in for the PAM program at all levels of the organisation
 - Full appreciation for the holistic, fully integrated processes, systems and organisation necessary.
 - Good communication and removal of institutional and organisational barriers to teamwork and coordination.
-
-

Adapted from Mitchell (2007).

Communication

Amadi-Echendu *et al.* (2010*b*) expect major PAM challenges to most likely to arise in the human dimension, in organisational settings and associated cognitive dispensations. Likewise, Woodhouse (2006) emphasised that momentum to PAM initiatives is accountable to the actions of people. Correspondingly, PAS 55 advised to effectively communicate the PAMS, PAM plans as well as pertinent PAM information to all relevant stakeholders. The specification further points out that asset management information is to be exchanged and understood throughout the organisation. Fogel (2012*a*) argues that the fact that people not understand the strategic process is one of the major obstacles to successful execution. He acknowledges, that generally, communication problems exist. Newman (2012) also agrees that information exchange is the “bottom-line” to align and coordinate the actions of different departments and to overcome resistance to change and silo-effects. It is not only across functions that information exchange plays an important role in execution efforts, but also along the organisational hierarchy. PAS 55 explains that effective communication is a two-way process, both top-down and bottom-up.

Gaining Support

PAS 55 clarifies that successful implementation of PAM requires the commitment of top management. More generally, it was outlined by Hrebiniak (2006) that successful strategy requires an ability to gain support for a particular course of action. Support is required both, vertically and horizontally, throughout the organisation. Analogously, Kellick (2010) outlines that executive support is a general success factor for the deployment of a PAM framework. Fogel (2012a) agrees and clarifies that the execution demands sponsorship by the organisation and that often PAM is not given enough space and resources to execute its strategy. This problem is also discussed by Govender (2012), he expects a shortage in employees to become a major issue in facilitating strategic initiatives. Mitchell (2007) also repeatedly stresses the importance of the energetic engagement and commitment of the greater management. Mitchell (2007) attributes the considerable performance losses of the PAM program to inadequate communication between reliability professionals and senior management. He clarifies that an PAM program must be driven top-down, led middle-out and accomplished bottom-up.

Power Structure

Hrebiniak (2006) remarks that the ability to form coalitions and gain the support of influential people in the organisation will help immensely with the execution of formulated plans. He states that working against the “power-structure” is bound to lead to failure. This is confirmed by Newman (2012), he points out that by departmentalising the PAM function, the organisational structure awarded PAM with more power to make an influence across functions. After enhancing the structure by departmentalising PAM, influencing and changing the mindset of other departments is the next step. In addition, Kellick (2010) is determined to establish a “shared vision” and to gain support for the asset management program. As Newman (2012) states that because PAM is cross-functional and involves areas within the organisation, it may encounter resistance when “interfering with someone else’s domain”. It is important to achieve a buy-in from the functions affected by the PAM initiatives.

Roles and Responsibilities

PAS 55 suggests that the organisation establishes and maintains roles, responsibilities and authorities consistent with the achievement of the physical asset management strategy, objectives and plans. It is emphasised that the organisational structure of roles, responsibilities and authorities plays a significant role in the successful implementation of PAM initiatives. Ideally, structures that create compartmentalised functions and responsibilities are avoided. This focus is shared by Stewart *et al.*

(2003) as well as Mitchell (2007). Stewart *et al.* (2003) suggest goals for the effective deployment of desired PAM improvements. The identification of structure, accountability, and responsibilities for the improvement program forms one important goal. Kellick (2010) agrees with this view, he points out that an PAM plan needs to be throughout the organisation and its success is reliant on different factors. The author identifies clarity of roles and responsibilities as a key success factors. It is vital that roles are made clear in a way that is agreed upon, understood and practiced. Correspondingly, Mitchell (2007) emphasises that it is vital to appoint and support persuasive and committed individuals who possess the power to instigate and lead change processes. The views are further supported by Fogel (2012a), who explains that according to his experience, each component of the strategy has to have an “owner” - a single point of accountability for milestones and goal achievement. The owner, according to Fogel (2012a), needs be harnessed with two qualities; he or she must be willing and capable. Fogel (2012a) emphasises that execution efforts rely on a “good and strong” person to drive the process, stating: “Then it happens”.

PAS 55 does not specifically introduce obstacles for the successful strategy execution. However, the standard presents important enablers for asset management. To a large extent these go hand-in-hand with the key principles of strategy execution, as referred to in Figure 2.4. In particular, Stewart *et al.* (2003), Kellick (2010) and Fogel (2012a) argue that clearly expressed responsibilities and accountabilities are crucial for the success of execution efforts. Newman (2012) explains that information flows are an indispensable enabler in driving asset management initiatives throughout the organisation. Due to the agency-wide characteristic of PAM, decision rights and information streams may be unclear and not effective, inducing problems to strategy execution. The strong emphasis on information flows and decision making is consistently echoed throughout publications of PAM. The views in PAM support the focus on the primary constraints stated by Mankins and Steele (2005) and Neilson *et al.* (2008). Moreover, Fogel (2012a) explicitly acknowledges an applicability of the strategy execution literature’s findings in the PAM environment. There is some overlap between the major obstacles identified by organisational research, and the expectations in the field of PAM. Additionally it was shown that the concepts of strategy execution are closely aligned. As a result, it is confidently believed that dysfunctional *information flow* and poor *decision making* are also evident in field of PAM as primary obstacles to the execution of its strategy.

The literature review has thus far portrayed the fundamentals of PAM and the contemporary traits of this field. Subsequently, the concept of strategy execution and the salient causes for its failure were elucidated. The findings of both spheres cul-

minated in the previous section, where the literature review singled out the primary constraints in PAMSE. The primary constraints that beset the PAMSE have been identified in the forms of information flow and decision making. In the following section, the essentials of Social Network Analysis (SNA) are introduced and the method is promoted as a means to unveil the primary constraints in PAMSE.

2.4 Social Network Analysis

The introduction presented a simple example of Social Network Analysis (SNA). For the benefit of the reader, the essentials that were gained from the previous example are revisited at this point.

A social network comprises of social entities that are connected by some relationship. A social entity may be an individual person, or an aggregate of social units such as an organisation. The investigated social units are typically referred to as *actors*. The relationship that connects two actors can be one of a various kind; common examples are friendship or kinship. In a collection of individuals, different people may be connected by different relationships. However, the SNA can focus one or more specific relationship(s). The selection of the relationship(s) under investigation is for the researcher to decide. In terms of this thesis, it may be assumed that the relationship is defined as “exchanging information”. A social network, consists of a number of individuals and the relationships of information exchange between them. The social network can be illustrated in a graph, in which every individual is represented by a node and every exchange of information is represented by a connecting tie between two individuals.

SNA is concerned with the analysis of a social network’s fabrics and is based on the assumption that the networks structure influences the actions of individuals. The following section elaborates on the theoretical concepts of SNA, in order to enable the development of an application methodology for PAM.

2.4.1 History

The conceptual evolution of SNA is convoluted. A variety of diverse stands, that sometimes crossed paths and sometimes diverged, shaped the present day SNA. The complex history of SNA is reviewed in great detail by Scott (2000), Freeman (2004) and Carrington and Scott (2011). Scott (2000) explains that the three main traditions that shaped SNA date back to the 1930s. They are the sociometric analysts who further developed the methods of graph theory, the Harvard researchers who

researched interpersonal relations and the Manchester anthropologists who relied on both traditions to explore the structure of community relations in tribal and village societies. According to Scott (2000) and Freeman (2011), it was in the 1960s and 1970s that the traditions were joined and that contemporary SNA was established. Carrington *et al.* (2005) point towards the events of the 1990s. After the initial phase of research in SNA, the interest and use of different methodologies picked up considerably. Different sciences and industries advocated the application of SNA and organisational SNA studies were recognised as being at the heart of management research. Yet, Carrington and Scott (2011) demonstrate that theoretical frameworks of SNA continued to evolve, and different methods and approaches found application in a great variety of studies.

Scott (2000) refrains from speculating if any theoretical framework will achieve predominance in the future. The author regards it unlikely that any single substantive theory should be regarded as embodying the essence of SNA. Recently, Carrington and Scott (2011) explained that although SNA is a well defined paradigm in its own right, it is embedded in diverse and traditional disciplines such as social psychology, social anthropology, communication science, organisational science, economics, geography and sociology. Scott (2000, p.37) contends that SNA has emerged as a set of methods for the analysis of social structures, specifically allowing for the analysis of relational aspects of these structures. SNA “embodies a particular theoretical orientation towards the structure of the social world and that is, therefore, linked with structural theories of action.”

2.4.2 The Social Network Perspective

Wasserman and Faust (1994) clarify that SNA is based on an assumption of the importance of relationships among interacting units. The interacting units in SNA is typically referred to as *actors*. Hanneman and Riddle (2011a) explain that the structure and behaviour of networks are grounded in and enacted by local interactions among actors. Mizruchi (1994) adds that the primary tenet of network analysis is that the structure of social relations determines the content of those relations⁵. In the words of Carrington *et al.* (2005, p.1), “the social contexts of actions matters.”

Wasserman and Faust (1994) point out that the social network perspective encompasses theories, models, and applications that are expressed in terms of relational concepts or processes. The growing interest and increased utilisation of SNA give rise

⁵A basic illustration on how the structure of social relations influences their content can be found in Simmel (1950).

to consensus regarding the central principles that underly the network perspective, these are shown in Table 2.9.

Table 2.9: The central principles underlying SNA.

| | |
|----|--|
| 1. | Relational concepts are fundamental to SNA. Linkages among actors define relations that are fundamental to social network theory. |
| 2. | Actors and their actions are viewed as interdependent rather than independent, autonomous units. |
| 3. | Relational ties (linkages) between actors are channels for transfer or “flow” of resources (either material or nonmaterial). |
| 4. | Network models focussing on individuals, view the network structural environment as providing opportunities or constraints on individual action. |
| 5. | Network models conceptualise structure (social, economic, political, and so forth) as lasting patterns of relations among actors. |

Adapted from Wasserman and Faust (1994).

In SNA, the unit of analysis is not the individual but an entity that encompasses the entire collection of individuals and relational ties among them. This is known as the social network. Marin and Wellman (2011, p.11) define a social network as “a set of socially relevant nodes connected by one or more relations”. A social network consists of a collection of actors and the ties between them. Each individual within this network is tied to another individual, each of whom is tied to a different set of actors. The pattern of relationships forms the *relational structure* among the collection of actors. Social network analysis can be used to study the structural variables measured on actors within a social network. Accordingly, Wasserman and Faust (1994) note that the collection of actors, the relational information on pairs of actors and possible attributes⁶ of the actors, constitute the collection of data that can be referred to as a *social relational system*.

2.4.3 Fundamental Concepts

The application of SNA demands the clarification of its underlying concepts. In order to avert confusion in terminology and to equip the reader with the required

⁶Wasserman and Faust (1994) explain that actor attribute variables are of the standard social and behavioural science variety and include classical measures such as gender, race or ethnicity. These measures will not form part of this study and will not be discussed any further.

understanding to follow the discussions of social networks in this thesis, this section presents very fundamental concepts of SNA.

Actor refers to any social entity, such as discrete individual-, corporate- or collective social units. Wasserman and Faust (1994) mention people in a group or departments within a corporation as typical examples. Actors are the unit of observation from which information about relational ties is elicited, they are the entity from which measurements are taken. De Nooy *et al.* (2011) show that graph theory employs the terms *point*, *node* or *vertex* alternatively and synonymously in order to represent actors.

Relational tie or simply **tie** describes the linkage of an actor pair. The range and type of ties can be of various natures. Some of the typical examples presented in Wasserman and Faust (1994) are the evaluation of one person by another, expressed as “friendship”, the transfer of material resources as “lending” or behavioural interaction as “talking”. The applications are expanded upon considerably in the literature.

Groups and set of actors are two closely related but distinct concepts. A group is a more or less restricted collection of actors (exemplary actors from different departments). Wasserman and Faust (1994) point out the importance of the researchers’ ability to argue in terms of theoretical, empirical or conceptual criteria that the actors in a group are somehow bound and belong together in a class. The entirety of actors which are subject to scrutiny, will consistently be referred to as an *actor set*. Collections of actors that are the same type are included in one actor set, which leads to *one-mode networks*. A one-mode network can contain many groups of actors, but only one actor set. For analytical reasons the set of actors is *finite*, this imposes the important issues of boundary definition and network sampling which are discussed as part of Chapter 3.

Relation describes the collection of ties of a specific kind among actors from a specific actor set. If two different types of relational ties (friendship and talking) are measured in an actor set, it can be referred to as two distinct relations.

Social Network consists of a finite set of actors, the relation(s) defined amongst them and the relational information that constitutes the network’s qualities. Wasserman and Faust (1994) point out that the presence of relational information is an important defining quality.

2.4.4 Definition

SNA has emerged from distinct theoretical frameworks. Inherently, SNA is an interdisciplinary endeavour. Scott (2000) also expresses the unlikelihood of one substantive theory being regarded as embodying the essence of SNA. Haythornthwaite (1996) explains that SNA is based on observed relationships of actors and therewith strives to empirically determine the social structure among them. Wasserman and Faust (1994) define SNA in terms of the central principles that it is based on, see Table 2.9. In addition, Freeman (2004) characterises SNA by means of a number of defining properties⁷. In the view of Carrington and Scott (2011) and Marin and Wellman (2011), SNA is a paradigm rather than a theory or method. Nevertheless, De Nooy *et al.* (2011) explain that the main goal of SNA is to detect and interpret patterns of social ties amongst actors. This thesis defines SNA as

“a research paradigm and collection of methods for the analysis of social relational systems.”

2.4.5 Structural versus Compositional Variables

Scott (2000) explains that social scientists have formulated distinct types of data, each of which have different methods of analysis assigned to them. Generally the distinction is made between “attribute data” and “relational data”. *Relational data* refers to contacts or connections between two actors, in other words, the relational ties. The data can not be reduced to the properties of one agent. Relational ties link one actor to another and connects pairs of actors into larger relational systems. According to Wasserman and Faust (1994) variables that are measured on pairs of actors measure a distinct relational structure, these are *structural variables*. *Attribute data* is accountable to the individual unit of analysis. According to Scott (2000), it relates to properties, qualities or characteristics of individuals. Possible examples are name, gender or age. The variables measuring attribute data are *compositional variables*. Scott (2000) emphasises the contention that SNA is appropriate for the analysis of relational data. However, Wasserman and Faust (1994) show that compositional variables can be included in SNA studies.

⁷1. SNA involves the intuition that links among social actors are important; 2. SNA is based on the collection and analysis of data that record social relations that link actors; 3. SNA draws heavily on graphic imagery to reveal and display the patterning of relational ties; 4. SNA develops mathematical and computational models to describe and explain those patterns.

2.4.6 Mathematical Representations

Mathematical representations in SNA, such as network data, graphs and matrices lie at the heart of the analysis conducted in this thesis. In some cases the theoretical concepts rely on different viewpoints of graph theory, sociometry and algebraic methods. The concepts may be very valuable for the reader's understanding, and this thesis attempts to concisely draw attention to the essentials⁸.

Level of Measurement and Relational Qualification

Social network data consists of the measurements on relations of one or more sets of actors. The level of measurement of network data can be distinguished by *directionality* and *numeration*. This characterisation refers to the network data and qualification of relational ties. The four main levels of measurement are shown in Figure 2.9.

| | | Directionality | |
|------------|---------------|-----------------------|--------------------|
| | | <i>Nondirectional</i> | <i>Directional</i> |
| Numeration | <i>Binary</i> | 1 | 3 |
| | <i>Valued</i> | 2 | 4 |

Figure 2.9: Levels of measurement in relational data.

Adapted from Scott (2000).

A nondirectional tie assumes an identical relationship between actor A and actor B as between actor B and actor A, the relational tie has no direction. Hence, if actor A exchanges resources with actor B, it is assumed that B also exchanges resources with A. Moreover, it may be worth considering the “strength” of the relationship between actor A and B. Scott (2000) explains that binary data indicates the mere presence of a tie, whereas values typically indicate the strength of a tie. That is, a binary value indicates if resources are exchanged or not and values quantify the strength of a tie. One example for measuring the strength of a tie is the “number” of resources that is transferred between the actors. A nondirectional and binary relationship makes up *Level 1* of relational data measurement. A nondirectional and valued relationship makes up *Level 2* of relational data measurement. Directional data considers specifically the directionality of a relationship, Wasserman and Faust

⁸For extensive explanations refer to Wasserman and Faust (1994), Scott (2000) and Scott and Carrington (2011).

(1994) clarify that here, the relational tie has an origin and a destination. The relational tie is directed from one actor to the other actor of a pair. A directional and binary relationship makes up *Level 3* of relational data measurement, whereas *Level 4* is directed and of valued numeration. In the light of resource exchange between actor A and B, relational data of *Level 4* can capture *who* transfers *the quantity of* resources to *whom*. The corresponding graph-theoretical illustrations are shown in Figure 2.10.

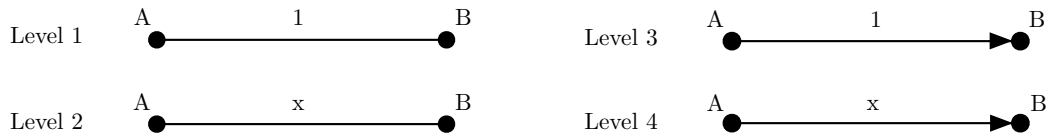


Figure 2.10: Directionality and numeration of relational ties.

Marin and Wellman (2011) explain that the decision to characterise ties as directed or undirected, or binary or valued are pragmatic choices. They are based on available data, methods of analysis and the expected theoretical benefit.

Mathematical Perspective on a Social Network

A social network can be described mathematically using graph-theoretical-, sociometric- and algebraic notation. Hanneman and Riddle (2011*b*) state that social network analysts use matrices and graphs as tools to represent network information.

For purposes of the following paragraph a single set of g actors is assumed. In terms of directional relations amongst actors, in which self-ties (loops) are not allowed, there are $g(g - 1)$ pairs of actors. Because the relationship among a pair of actors n_i and n_j is directional the pair’s “order matters” and it is thus called an *ordered pair*. It provides information that is asymmetric and not necessarily reciprocated. The set of \mathcal{L} contains the collection of ordered pairs $\langle n_i, n_j \rangle$ which have ties. Graphically, the elements in \mathcal{L} can be presented by drawing a line from the first actor in the element to the second actor. A directed line is referred to as an *arc* l_i . Because the lines have a direction, this graph is customarily referred to as a *directed graph*. A basic example of a directed graph is shown in Figure 2.11. Thus a directed graph, which shall be denoted by \mathcal{G}_d can be described by a set of nodes $\mathcal{N} = \{n_1, n_2, \dots, n_g\}$ and a set of arcs $\mathcal{L} = \{l_1, l_2, \dots, l_L\}$. Amongst other network methodologists Freeman (1989) refer to the set of actors and the set of lines as the

algebraic structure $S = \langle \mathcal{N}, \mathcal{L} \rangle$. According to Wasserman and Faust (1994), S is the standard representation of the simplest possible network.

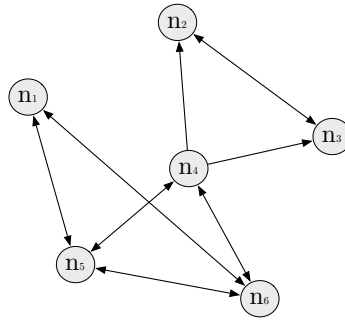


Figure 2.11: Directed graph.

For unvalued data, a binary quantity x_{ij} is defined to be equal to 1 if the ordered pair $\langle n_i, n_j \rangle$ is an element of \mathcal{L} . There is thus a directional tie from n_i to n_j ($n_i \rightarrow n_j$). The quantity x_{ij} is equal to 0 if no tie is present between the actor pair. These quantities form the elements of a binary $g \times g$ sociomatrix \mathbf{X} . Table 2.10 shows a simple sociomatrix for the directed graph above. It may be noted that sociomatrices are *adjacency matrices* for graphs and therewith illustrate how notational schemes of sociometry and graph theory interrelate. The elements along the diagonal do not have values because the graph does not contain any self-ties of actors, so called loops.

Following Freeman (1989), the triple consisting of the algebraic structure S , the directed graph (or sociogram) \mathcal{G} and the sociomatrix (or adjacency matrix) \mathbf{X} defines a social network.

$$\mathcal{S} = \langle S, \mathcal{G}_d, \mathbf{X} \rangle \quad (2.1)$$

This triple delivers a more abstract definition of a social network. Wasserman and Faust (1994) point out that it demonstrates how the three notational schemes are combined in order to describe “the simplest form” of a social network. Further, it is pointed out that much of the modifications of this simple network \mathcal{S} , such as valued relations or multiple relations, can be viewed in the same way. The graph that relies on valued relations is named a *valued graph*. Mathematically, a valued graph \mathcal{G}_v consists of the set of nodes, \mathcal{N} , a set of arcs \mathcal{L} and a set of values $\mathcal{V} = \{v_1, v_2, \dots, v_g\}$ denoted as $\mathcal{G}_v = \langle \mathcal{N}, \mathcal{L}, \mathcal{V} \rangle$.

Table 2.10: Adjacency matrix for six actors and a single relation.

| | n_1 | n_2 | n_3 | n_4 | n_5 | n_6 |
|-------|-------|-------|-------|-------|-------|-------|
| n_1 | - | 0 | 0 | 0 | 1 | 1 |
| n_2 | 0 | - | 1 | 1 | 0 | 0 |
| n_3 | 0 | 1 | - | 1 | 0 | 0 |
| n_4 | 0 | 0 | 0 | - | 1 | 1 |
| n_5 | 1 | 0 | 0 | 1 | - | 1 |
| n_6 | 1 | 0 | 0 | 1 | 1 | - |

2.5 Informal Networks in Physical Asset Management Strategy Execution

On the basis of the “Hawthorne studies”⁹ and the constructed sociograms, Roethlisberger and Dickson (1939) identified an *informal organisation* in addition to the *formal organisation* that was depicted on the organisational chart. The informal organisation reflects the empirically determined informal working dynamics, as opposed to the formal working structure. An analogy presented by Krackhardt and Hanson (1993, p.104) suggests that the formal organisation is no more than the “skeleton” of a company, the informal organisation in turn, is “the central nervous system”, driving the collective thought processes and actions. Cross *et al.* (2002a) argues that the informal relationships among employees are often far more reflective of the dynamics inside a company. They are much more capable of describing how “work happens” than relationships established by positions within the formal structure. Hanneman and Riddle (2011a, p.340) say that “differences among actors are traced to the constraints and opportunities from how they are embedded in networks.” Cross *et al.* (2001) point out that SNA offers rich and structured means of assessing informal networks. The relations amongst people, teams or entire organisations can be analysed and mapped.

⁹From 1924 to 1933 Elton Mayo, professor of industrial management at Harvard Business School and his protégé Fritz J. Roethlisberger led a landmark study of worker behaviour in the Western Electric “Hawthorne plant” near Chicago, Illinois. According to Harvard Business School (2012), “Harvard’s role in the Hawthorne experiments gave rise to the modern application of social science to organization life and lay the foundation for the human relations movement and the field of organizational behavior”; the study of organisations as social systems.

CHAPTER 2. LITERATURE REVIEW AND CONTEXTUALISATION OF STUDY 60

The examination of informal networks with SNA is practiced in various contexts. Cross *et al.* (2010a) demonstrate that research topics include competitive advantage, innovation, customer retention and profitability, leadership effectiveness, talent management, and quality of work life. The work by Chinowsky *et al.* (2010) shows that lately, SNA has also received attention within the field of engineering. The authors successfully utilise SNA in order to discern communication barriers between the regional and corporate offices of a structural engineering organisation. Apart from this, Cross *et al.* (2001) conduct a SNA in the exploration and production division of a large petroleum organisation in order to investigate the collaboration between executives. The analysis yielded an array of problem areas that limited the flow of information among executives and needed to be addressed.

Mitchell (2007) emphasises that organisational conflicts in change processes surrounding PAM are typically more pervasive and difficult to solve than technical issues. SNA may stand a chance in discerning informal network structures that aid the understanding of execution dynamics or picture contrast to the the formal structure behind strategic initiatives. Cross *et al.* (2002a, p.26) state that SNA can be “an invaluable tool for systematically assessing and then intervening at critical points within an informal network”. Krackhardt and Hanson (1993) explain that using SNA enables managers to translate relational ties into maps that illustrate how work “gets done”. More specifically, Cross *et al.* (2002b) show that SNA is capable of equipping managers to visualise and understand the myriad of relationships that can either facilitate or impede collaboration. Accordingly, questions like “How does information flow within an organisation? To whom do people turn for advice? Have subgroups emerged that are not sharing what they know as effectively as they should?” can typically be answered by SNA. Cross *et al.* (In Press) demonstrate an application of SNA to scrutinise decision making inside organisations. At the most rudimentary level, Cross *et al.* (2002a) find that visually assessing the pattern of relationships within a group can reveal a selection of actionable points. One example is the opportunity to identify people who are highly central in a network. These people could disproportionately impact a group by controlling the information transfer and the decision making.

In the context of PAM, Tsang (2002) also recognises that informal communication channels between people exist and information rapidly passes through them. He says that an understanding of behaviour at work and parameters of group effectiveness will yield better organisational design, fostering employee commitment and chances of success in change programs. De Nooy *et al.* (2011) find that people in crucial positions in the information network may spread or retain information

strategically because they have control over the diffusion of information. Ties offer access to information which can be used to reduce uncertainty, risk and build trust. Rogers and Blenko (2006) argue that the organisation can improve decision making and therewith improve strategy implementation, on condition that bottlenecks in the flow of information are located and people with the power to break through them can be found. Strategy execution involves communication and coordination of *key* employees. Colella (2010) proposes SNA as a method to hand pick the employees who have critical roles in strategy execution. Further, SNA may uncover isolated groups that are required to collaborate but aren't tied properly; or discover employees with key roles in networks, enabling highly targeted workshops and training. Cross *et al.* (2002a, p.28) find that SNA is uniquely effective in “promoting effective collaboration within a strategically important group; supporting critical junctures in networks that cross functional, hierarchical, or geographic boundaries; and ensuring integration within groups following strategic restructuring initiatives.” Evidently, SNA offers means to assess the areas of concern that are highlighted in PAMSE.

An organisation's informal dynamics may impair or foster execution efforts. SNA can be utilised to carefully examine informal networks within organisations. SNA is also evidently proficient in deciphering information flows and decision making, that have been identified as primary constraints in PAMSE. The approach of SNA is not limited by formal organisational structures and processes, instead, SNA breaks through formal working structures and reflects on the empirically determined informal working dynamics. SNA thus echoes the cross-functional character and focus on the human dimension that emerges in PAM. SNA emerges as being particularly suitable for an application in the field of PAM and analysis of the primary constraints in PAMSE.

However, as Cross *et al.* (2002a) argues, while it has been demonstrated that informal networks pervade and effect life and work within organisations, the means of how to assess and support informal networks often remain withheld from practitioners; mostly due to the technical nature of the publications and network terminology employed. PAS 55 suggests that in establishing the PAMS, the organisation should consider opportunities, such as advances in management practices, to achieve the PAMS in more effective ways. Taking a network perspective in analysing the primary constraints in PAMSE is potentially such an opportunity.

2.6 Chapter Summary

The literature review addresses the key concepts that are at the heart of this thesis' research domain and essential to develop a solution to the stated problem. Ultimately, Chapter 2 aims to contextualise the present problem areas in PAMSE and the matching capabilities of SNA.

The first two sections of the literature review convey a fundamental understanding of PAM and strategy execution. In essence, it is shown that today's PAM places great emphasis on an agency wide perspective and sharpens its focus on the human and strategic dimension. Furthermore, it is highlighted that while the field of strategic management contains a great variety of concepts, the interest in strategy execution has only recently gained momentum. Similarly, the present literature in PAM falls short of vigorously discussing the properties of strategy execution, although it is emphasised that the execution capabilities determine the success of a strategy. Nevertheless, it is shown that PAMSE aligns the strategy execution conceptualisation, established by management science very well. On the basis thereof, the findings from management research and PAM are contextualised in order to delineate the concept of PAMSE. As a result, a workable definition for PAMSE is derived. Chapter 2 thus achieves the first research objective of this thesis; the fundamentals of PAM and PAMSE are established.

A number of daunting challenges to effective strategy execution are then discovered in the management literature. The research by Mankins and Steele (2005) and Neilson *et al.* (2008) sharpens the focus on information flow and decision making as salient problem areas. On the basis of publications in PAM and the dialogue with experienced PAM practitioners (use of qualitative research methods), the preponderance of these impediments have been confirmed for the PAM environment. Hence, Chapter 2 achieves the second research objective: information flow and decision making are singled out as the primary constraints in PAMSE. Thereafter, the literature review provides an introductory comprehension of SNA. The essential elements that constitute the network perspective are outlined and SNA is introduced as a research paradigm and collection of methods to assess social relational systems. Consequently, the third research objective is achieved.

At this point, the contemporary traits of PAM and the primary constraints in its strategy execution are matched with the concept of SNA. Chapter 2 closes with contextualising the findings from both disciplines. The literature review highlights the existence of informal networks that accompany PAMSE and demonstrates that

informal networks may dictate the context of actions within an organisation. The formally defined hierarchy frames working structures, while SNA empirically determines the informal dynamics behind the organisational chart. Informal networks mirror working dynamics and can be investigated in order to detect the primary constraints in PAMSE. Apart from this it is noted that the concept of SNA complements the characteristics of today's PAM. The research paradigm allows for the investigation of cross-functional organisational settings and pays particular attention to the focus on the human dimension. The literature review thus achieves the fourth research objective, which is that the findings from PAMSE and SNA are contextualised. The exhaustive review of literature achieves the defined research objectives and thereby provides the essentials for the development of a SNA application methodology aimed at discerning primary constraints in PAMSE.

The good management of physical assets is a crucial factor in the success of asset-centric organisations. The PAMS can, however, only reach its targets if executed successfully. An alarmingly high rate of failure in strategy execution processes draws the attention to the reasons of failure and demonstrates the importance in harnessing means against the primary constraints in PAMSE. Although researchers point towards salient areas of concern, specific problems in the organisation are difficult to pinpoint which makes resolving the issues more difficult. The problem is that the means to detect the primary constraints in PAMSE are deficient.

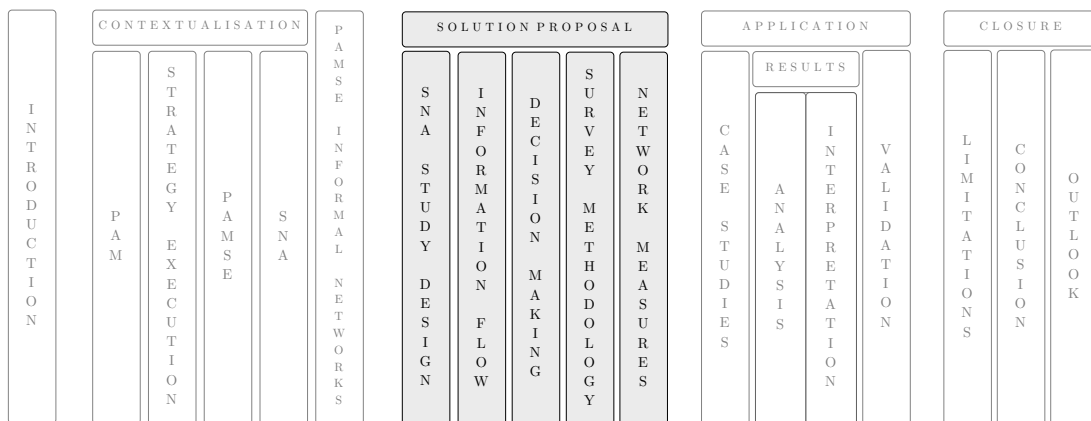
In the context of the contemporary traits of the PAM field and the major problem areas in strategy execution, the capabilities of SNA may be a powerful means to address the challenges in PAMSE. If SNA can map the primary constraints in PAMSE, corrective action can be precisely directed in order to remove salient constraints. Management may manipulate the network structure in areas of concern and therewith the interactions of network members, fostering a successful strategy execution process. This may in turn result in better compliance to strategic goals and eventually generate value for the organisation. SNA may provide valuable insight from a very different perspective that eventually facilitates the achievement of an organisation's strategic goals. Although the means of SNA have been around for a long time, the application was limited to a few. This is the motivation for the investigation of SNA as a method to map the primary constraints in PAMSE. Therefore, the following chapter develops a SNA application methodology for assessing the informal networks of information flows and decision making in a PAM environment. After the approach for a SNA application is established, Chapter 4 utilises the developed methodology at two research sites in order to test the capabilities of SNA in the PAM environment.

Chapter 3

Social Network Analysis Application Methodology

Chapter Aim:

The aim of this chapter is to develop a robust SNA application methodology, in order to explore the informal networks of information flow and decision making in PAMSE.



Chapter Outcomes:

- Preliminary considerations of the SNA application.
- SNA study design and boundary definition.
- An approach to analysing information flow.
- An approach to analysing decision making.
- Adequate methods for data collection.
- Presentation of measures to explore informal networks.

3.1 Basic Steps

The problem statement in Chapter 1 found that the current means to detect major constraints in PAMSE are deficient. However, enhancing an organisation's execution capability may realise benefits in an area of opportunity that remains largely untouched at present. In order to address the present challenges in PAM, this thesis proposed SNA as a means to map the the primary constraints in PAMSE. The literature review introduced the fundamentals for a study that investigates an application of SNA in the PAM environment. Notably, Chapter 2 conveyed an understanding of PAM, PAMSE and SNA. Furthermore, Chapter 2 singled out dysfunctional information exchange and poor decision making as the primary constraints in PAMSE and showed that SNA stands a chance of discerning problems in these domains.

So far, the research problem and the domains that surround it were clarified. The literature review gave reason for investigation into the application of SNA in PAM and laid out the basic knowledge for this ambition. Chapter 3 develops a robust SNA application methodology, in order to explore the informal networks of information flow and decision making in PAMSE. The principal step sequence of the SNA application methodology, as proposed here, is comprised of the five consecutive phases shown in Figure 3.1. Each phase is outlined below.

Phase 1: Preliminary Considerations

Phase 1 makes preliminary considerations for the SNA application. At the outset it is expedient to clarify the aim of the application. After that, the circumscription of the field of application enables the selection of suitable research sites. Furthermore, it is decided on the social entities on that social network data is to be collected.

Phase 2: SNA Design and Boundary

After the preliminaries for an application are outlined, the second phase of the application methodology establishes the framework of the SNA. The social network study design chooses the network type that determines the use of structural measures. Furthermore, the application methodology guides the selection of network members through the definition of network boundaries.

Phase 3: Constructing Networks

At this point, the application methodology enables the identification of the entirety of actors that are chosen to feature in the network study. However, no decisions regarding specific relations have been made, yet. Hence, the qualities of the ties that connect the actors are still undefined. Therefore, two approaches to investigate the

informal networks of information flow and decision making are developed. These approaches determine the relations that are defined on the actors. From the definition of relations, survey questions are derived that enable the collection of empirical network data. The defined relations and corresponding survey questions ground the construction of informal networks that connect the collective of actors within the defined network boundaries.

Phase 4: Collecting Data

After developing the theoretical framework for the SNA application, the fourth phase of the SNA application methodology concerns the creation of a survey methodology, suitable for collecting social network data at research sites.

Phase 5: Analysing Networks

After the means for data collection are established; Phase 5 of the application methodology presents the network properties and structural calculations that are used to explore the informal networks of information flow and decision making. The analysis of the constructed networks ideally leads to the discovery of results and achieves the stated application aim: mapping primary constraints in PAMSE.

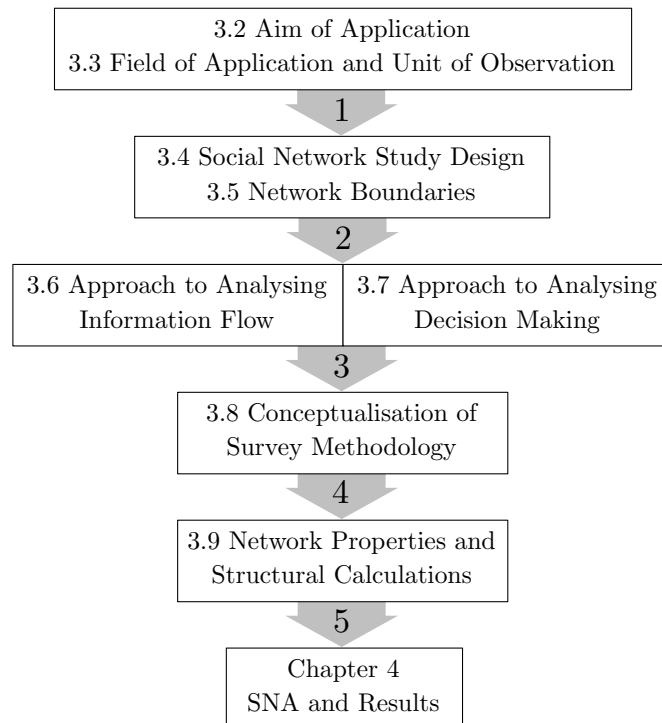


Figure 3.1: Basic steps of the SNA application methodology.

3.2 Aim of Application and Research Hypothesis

The following two sections introduce the preliminaries for a SNA application; they correspond to the inaugural Phase 1 of the SNA application methodology.

The application of a SNA in PAM can pursue very different aims. Here, the aims of the application are rooted in the purpose of this thesis. A SNA is applied, in order to investigate whether the method can map primary constraints in PAMSE. The null hypothesis is stated as:

H_0 : Social network analysis can not be used as a method to map primary constraints in physical asset management strategy execution.

On the basis of the literature review and the dialogue with experienced practitioners, information flow and decision making have been identified as the two salient areas of concern. Therefore, the SNA application methodology is determined to decipher constraints in these problem areas. Hence, the aim of the SNA application is to *map primary constraints in the domains of information flow and decision making in PAMSE*.

3.3 Field of Application and Unit of Observation

The field of application is an important consideration for the SNA application as it regards the identification of suitable research sites. For the SNA application in this thesis, the field of application is limited to *asset-centric organisations*; it is limited to those organisations whose core business significantly rely on the performance and management of physical assets. It may be noted that such organisations that fulfil the application criteria of PAS 55 are suitable cooperation partners for this study, see Table 2.3.

In SNA the unit of analysis is social relational systems, it is the networks that are grounded in one or more relations. As the unit of observation can be any social entity, various options for the selection of the unit of observation arise in PAM. Here, two different approaches are outlined. An organisation may have a centralised PAM function that is responsible for multiple plants. In this case the unit of observation can be selected as the social aggregate units representing the different plants and the organisation's PAM department. Thus, the SNA focusses on the "high-level" informal networks that span over different operations and the PAM function. It may also be that each plant contains an integrated PAM function. A different approach

may zoom in on a particular plant and choose its staff as the unit of observation. In this case, the informal networks capture the working dynamics between the different organisational functions that operate the plant. The two different approaches in selecting the unit of observation are illustrated in Figure 3.2.

For the purpose of this thesis, the unit of observation is selected as *the staff of one particular plant of an asset-centric organisation*. As an additional criteria, not every employee of the plant is considered by this study. Network data is only collected on those individuals that fall within the network boundaries specified in Section 3.5. It may be noted that SNA is scalable, and thus can incorporate the staff of multiple plants into one study. However, this approach is not subject to this thesis.

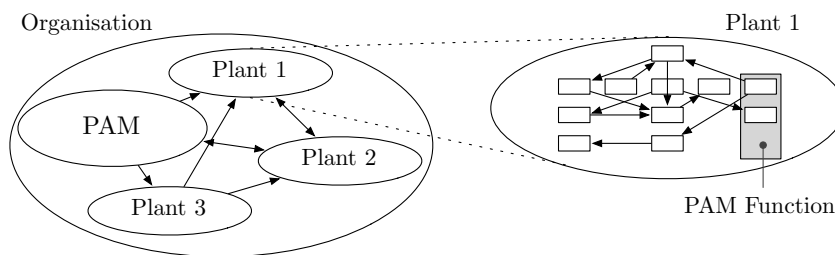


Figure 3.2: Different units of observation.

3.4 Social Network Study Design

The preliminaries for a SNA application were established. The following section engages in Phase 2 of the SNA application methodology. The second phase clarifies the theoretical choices regarding the social network study design and the boundary definition.

Marin and Wellman (2011) advise that prior to network data collection it has to be decided what kind of network and relations will be studied. Social network studies choose a “whole network” or “egocentric network” design. The distinction between these two kinds of networks pervades publications and is echoed by numerous authors¹. Marsden (2005) clarifies that whole networks focus on all actors that are, for analytical purposes, regarded as a bounded social collective. Hanneman and Riddle (2011a) explain that egocentric studies privilege the network surrounding a particular actor in focussing on the relationships in the actor’s locality.

¹See for example Scott (2000), Cross *et al.* (2006) and Marsden (2005, 2011).

This thesis aims to investigate the constraints in PAMSE. The execution of strategic initiatives is not facilitated by a single individual. Rather, the strategy execution relies on the collaborative action between the employees from different departments and the leadership of different managers. Therefore, this thesis adopts a *whole network* approach. The social collective that is to be analysed is bound to a research partner, a cooperating asset-centric organisation. The specific actor set for a case study is encompassed through the definition of a network boundary, see Section 3.5 and 4.1 respectively. Marin and Wellman (2011) state that researchers using whole network data frequently analyse more than one relation, collapsing relations into single networks. This is applicable to this study. It is intended to collapse the domains of information flow and decision making into a number of distinct relations. The constructed informal networks will refer to each relation respectively. The analysis in this thesis relies on a *single set* of actors for each case study, so called *one-mode* networks. Marin and Wellman (2011) find that most whole network studies analyse one-mode networks. Therefore, the approach taken by thesis may be regarded as being typical. The network type in this thesis is defined as whole network and one-mode.

In line with the tenet of SNA, this study will primarily draw on structural variables and merely incorporates *one single compositional variable*. In order to attribute a function or department to every actor, it is required to capture an actor's job position. Apart from this, it may be noted that the study restricts itself to *exploratory* SNA network analysis. Explanatory SNA that involves specific hypothesis testing on networks falls outside the ambitions of this study. Moreover, the SNA study design *does not allow for self-ties* (loops). This thesis focusses on the relationship between actors, a self citation is thus of no theoretical concern and not meaningful to the analysis.

After defining the network type, Marin and Wellman (2011) recommend to subsequently identify the relations of theoretical importance and their respective level of measurement. This is done in the following sections. Section 3.5 defines the boundaries of the network study and Section 3.6 and 3.7 present the relations under investigation.

3.5 Network Boundaries

Prior to gathering data a number of concerns arise in network studies. Scott (2000) states that the network data selection poses considerable problems for SNA. Concerns involve the limits of social relations and the possibility of drawing relational

data from samples. Wasserman and Faust (1994) explain that while network research may see the social world consisting of many, possibly infinite connections, it finds that effective and reasonable limits can be placed on the inclusion of actors in a study. According to Scott (2000, p.54), the “determination of boundaries in a research project is the outcome of a theoretically informed decision of what is significant in the situation under investigation.” The definition of a network boundary enables the researcher to identify the *relevant* population for a study. Wasserman and Faust (1994) mention that the researcher has to identify the population to be studied and sampling methods have to be contemplated, if required. That is, it to be answered, who the relevant actors are and which actors are in the population. Marsden (2005) states that in whole-network studies, the decision on actor set(s) is difficult. Laumann *et al.* (1989) present three generic approaches to define the network boundary. The *positional* approach relies on characteristics of actors or formal membership criteria. The *event-based* approach is based on actor participation in some class of activities. The *relational* approach is based on social connectedness. Laumann *et al.* (1989) also distinguish between a *realist* and a *normalist* approach in boundary definition. The former approach focusses on the boundary definition as perceived by the actors themselves, while the latter rests upon the theoretical concerns of the researcher. In the following, it is argued for reasonable boundaries that match the scope of this thesis. The realist and, just as well, the normalist point of view will be considered to encircle the population of concern.

Normalist Perspective

From a normalist point of view, it may be referred to Wasserman and Faust (1994), who state that sometimes a clear external definition of the boundary exists that enables identification of an appropriate actor set. One positional example for such definition is the employment by an organisation, as outlined by Krackhardt (1990). The application of SNA will be facilitated by a research partnership with a cooperating asset-centric organisation. It is argued that the employees of the cooperating company are bound by their employment relationship. This makes up for a positional argument to set the boundary around all employees in the studied organisation. For the case that an organisation operates multiple plants, it may be reasonable to limit the study to a particular operation. Hence, a second positional argument reduces the study boundary to individuals that are employed to a specific operation. Moreover, the selection may be further decreased by the event-based criterion of actor participation. The purpose of this thesis requires employees to have significant involvement in PAMSE. Therefore, departments and employees which are not immediately involved in PAM fall outside the boundaries of this study. At the same time this argument may add actors that are not formally part of the organisation but play an important

role in PAMSE. Consultants that assist an organisation may be a plausible example. The resulting network boundary definition on the basis of a normalist perspective is illustrated in Figure 3.3.

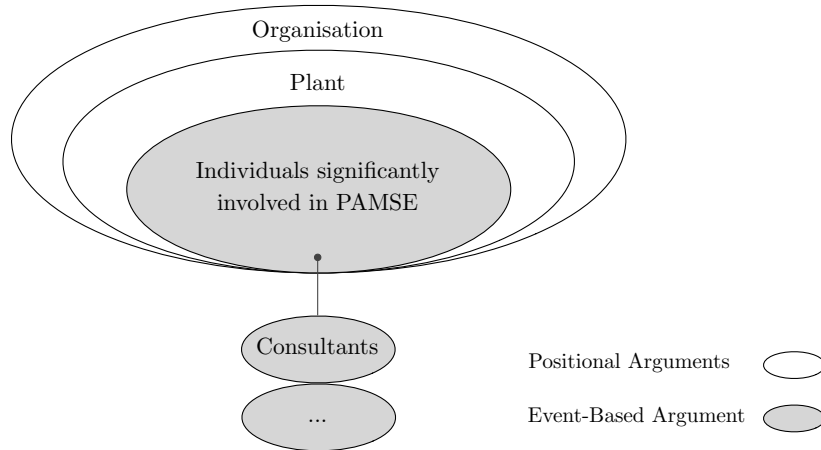


Figure 3.3: Network boundary definition on the basis of a normalist perspective.

Scott (2000) states that it is a common strategy to identify all particular actors in small scale social networks and to detect their ties. Following this approach, a *fixed list* of the *relevant* actors for this study is constructed. In consultation with managers of the organisation under investigation, the relevant actors are identified. Each actor's personal details may be derived from organisational records. Consequently, the actor set of concern can be enumerated. This procedure is referred to as the *fixed list method*.

Realist Perspective

From a realist point of view, clearly identifiable actors of the network may be given the opportunity to add additional actors to the prepared fixed list. Actors that are identified on basis of normalist arguments may add the actors that they maintain ties to. Then, network boundaries are defined as sensed by the network members themselves. That is, data collection begins with a provisional list of actors who are deemed to be in the network of study. Subsequently, the perceptions of identified actors will be used to supplement the network by adding more actors. However, Doreian and Woodard (1992) and Wasserman and Faust (1994) agree that, strictly speaking, it is not even required to present the actors with the list of actors that they have been chosen from. Marsden (2005) states that this method is based on relational criteria. The method is termed *expanding selection* and is outlined and opposed to the fixed list method in Doreian and Woodard (1992). In principal, the

expanding selection is illustrated in Figure 3.4. Actors that are identified by taking a normalist perspective expand the selection of network members by referring to additional individuals that they maintain “significant” ties to. For an application in PAM the expanding selection method is particularly advantageous. The preparation of fixed lists according to positional and event-based criteria can fail to capture individuals that are important to the plant. Exemplary, the engineers of one plant may interact with the staff from other organisational resorts or plants. This part of the network is systematically excluded by taking a normalist perspective only. However, a connection that transcends the boundary defined by a normalist argument can be of significance to the analysis. Therefore, this thesis chooses to rely on a combination of normalist and realist perspective and uses the expanding selection methodology, in order to set the networks’ boundaries.

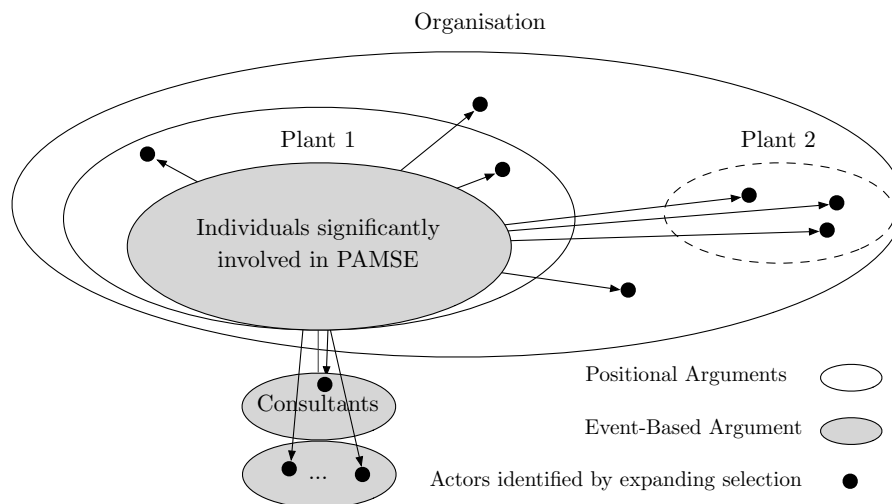


Figure 3.4: Network boundary definition on the basis of a realist perspective.

3.6 An Approach to Analysing Information Flow

The previous sections defined the aim and field of the application as well as the unit of observation. Furthermore, the boundaries for the SNA application were set. Hence, an actor set can now be identified. However, the relations that connect the actors are not established, yet. The following sections addresses Phase 3 of the SNA application methodology. The sections concern the construction of the informal networks that are subject to the SNA.

SNA can be understood as an approach and set of techniques to study the exchange of material or non-material resources. Amongst others, Wasserman and Faust (1994) specifically name the transfer of non-material resources in communication and information exchange as relations that have been studied. Scott (2000) shows that the first analysis of information flow date back to the 1930s and the “gestalt” theory, that was one of the processor in the lineage of SNA. Haythornthwaite (1996) agrees with Wasserman and Faust (1994), the author explains that information is one such non-material resource to be studied using SNA. Haythornthwaite (1996) argues that SNA offers a rich variety of concepts and techniques that describe information exchange. The author explains how SNA can be and has been applied to the study of information flow. Various applications of SNA to analyse information flow can be found in Krackhardt and Hanson (1993), Cross *et al.* (2001, 2002*b,a*, 2010*a*) and Chinowsky *et al.* (2010).

Information exchange networks may consist of individuals as actors and information exchange relations as ties between them. Figuratively speaking, just as shipping routes structure the flow of resources among harbours, information exchange relationships structure the flow of information among actors. Haythornthwaite (1996) explains that both, the content and the pattern of relationships are examined by SNA, in order to investigate *how* and *what* resources are exchanged between actors. Accordingly, it is required to ask about the kinds of information, the pairs between it is exchanged and “how much” information is exchanged. Thus, Haythornthwaite (1996) derives three attributes of relationships, namely the *content*, *direction* and *strength*. The relations, that are selected in front of the background of the thesis’ purpose align to these attributes. Multiple relations can be measured on a single set of actors. Therefore, surveys may include a collection of questions that investigate *who* is turned to, in order to get what *kind* of information and at which *frequency* interactions take place. In addition, the research design can specify the *quality* or *quantity* of exchanged information as well as the communication mode (e.g. email, phone or meeting). Above all, the questioning can be formulated to specifically elicit an information flow that is related to a certain subject area.

3.6.1 Analytical Scope

Müller-Prothmann (2006) advises that for the examination of networks, the scope of analysis must be clearly defined. In this thesis the analysis does neither focus on the quality of exchanged information nor on the mode in which communication takes place. Investigations concerned with the quality of information and the modes utilised to communicate fall outside the scope of this thesis. Rather, the intent of

this study is to elucidate *who* exchanges information with *whom*, regarding which *subject*, at which *frequency*.

This thesis does not only consider the mere existence or non-existence of a tie. Rather, tie strengths as well as the properties of interaction are considered to be important. The intensity, or strength of a relationship is characterised by a certain *frequency* that interactions take place. Research by Van Wijk *et al.* (2008) suggests that amongst the various factors that influence knowledge transfer there is strong evidence of tie strength and trust being the major factors. A collection of secondary factors can be found in Van Wijk *et al.* (2008) or Chinowsky *et al.* (2010).

The main tenet of this thesis is that tie strength and trust between actors are the most significant facilitators of information exchange. This brings this study to limit itself to the investigation of these factors. Although it is desisted from investigating secondary influences to information exchange; it is recognised that other influencing factors coexist beyond the scope of this thesis.

3.6.2 Relations of the Information Exchange Network

The analytical scope contoured the ambitions of the information exchange analysis. For the purpose of this thesis, the relation of information exchange \mathcal{X}_1 and the relation of PAM information exchange \mathcal{X}_2 are formulated. The relations and the corresponding survey questions are shown in Table 3.1.

Table 3.1: Relations of information exchange.

| \mathcal{X}_r | Relation | Structural Variable / Survey Question | Attribute(s) |
|-----------------|---|---|---------------------|
| \mathcal{X}_1 | Information exchange | Who do you typically receive work related information from? | Content & Direction |
| | Strength of information exchange ties | How often do you typically receive work related information from this person? | Strength |
| \mathcal{X}_2 | PAM information exchange | Who do you typically receive PAM related information from? | Content & Direction |
| | Strength of PAM information exchange ties | How often do you receive PAM related information from this person? | Strength |

Haythornthwaite (1996) presents three attributes of relationships that were derived from key questions in information exchange. *Content* describes the subject of interest that is represented by a relation. For relation \mathcal{X}_1 the content is specifically defined as work related information; for relation \mathcal{X}_2 as PAM related information. The study notes the importance of a distinction between the two streams of information. Employees exchanging work-related information do not necessarily converse about PAM. It may be beneficial to oppose work-related communication and the flows of PAM information.

The *direction* of the information flow is described by receiving and providing information. Where an individual indicates that he or she receives information, the information flow is clearly directed towards the receiving individual. Hence, the examined relationships are directed and reveal source or sink of transferred information. Marin and Wellman (2011) concur with this convention, the authors state that information flows are directed ties. The strong argument is that information flow involves a particular direction because a reciprocity of information exchange can not be implied.

Strength refers to the intensity of a relationship. Scott (2000) argues that the measure of tie strength should rest upon an argument that produced solid theoretical or empirical reasons for treating the data in this way. This evidence is given by Granovetter (1982) and Lin and Bian (1991). The authors find that strong² ties are important for information exchange. With reference to the work of Festinger *et al.* (1950), it can be said that strong ties have long been considered to be conducive to the exchange of information. Additionally the work of Rowley *et al.* (2000) and Reagans and McEvily (2003) reaffirmed this evidence and suggest that strong ties lead to greater knowledge transfer. Haythornthwaite (1996) states that strong ties connote the willingness to share information. Haythornthwaite (1996) explains that the decision on what to measure to determine tie strength becomes problematic. Mainly, because a context-dependent measure, of what constitutes “closeness” in a tie, is required.

Hansen (1999) explains that tie strength reflects the “closeness” of a relationship between individuals. The strength of a tie increases with frequency of interaction and communication. Further, Wasserman and Faust (1994) explain that the use of valued relations that refer to frequencies of interactions among actor pairs is common

²Research by Granovetter (1973) and Levin and Cross (2004) also argues for the “strengths” of weak ties in information and knowledge transfer. Correspondingly, Haythornthwaite (1996, p.328) concludes that while strong ties connote the willingness to share information, weakly tied individuals “may have access to more and different information due to their connections in different networks”.

practice. Accordingly, Haythornthwaite (1996) and Marin and Wellman (2011) state that the tie strength may be measured by the amount of exchanged resources or frequency of contact. Because an “amount” of information is difficult to measure, the intensity of relationships are gathered through frequencies of predefined time intervals, represented by an integer. Consequently, the level of measurement for relation \mathcal{X}_1 and \mathcal{X}_2 is chosen as Level 4, it is *directed* and *valued*.

3.6.3 Network of Trust

It was shown that amongst the various factors that influence information transfer, there is strong evidence of tie strength and trust being major factors. The influence of trust shall be addressed by a separate relation. The work by Krackhardt and Hanson (1993) clearly documents benefits of analysing a trust network within an organisation. The authors recommend investigating trust when major changes are introduced or crisis is experienced. Despite the theoretical considerations, this advice particularly motivates the creation of a trust relation in the light of strategic PAM initiatives.

It is important to raise awareness for the two fold influence of the trust relation. Firstly, trust facilitates the exchange of non-material resources. This view is widely shared throughout the literature. Research by Lane *et al.* (2001), Szulanski *et al.* (2004) and Van Wijk *et al.* (2008) indicates that trust between individuals facilitates³ organisational knowledge transfer. Inkpen and Tsang (2005) and Lane *et al.* (2001) also argue that trust plays an important role in the willingness of actors to share information. Moreover, Blasnales (2010, p.72) says that “distrust is sand in the organizational gears”. Distrust impedes information flow. Furthermore, Blasnales (2010) shows that SNA can inform problem diagnosis in trusted ties and information flow within the organisation as well as the design of improvement projects. Secondly, it has to be noted that while tie strength and trust influence information exchange, trust also influences the tie strength of a relationship. Haythornthwaite (1996) expresses that the strength of ties may, among the number and type of relationships that are maintained by a pair, depend on the individual relationships. The more personal a relationship is, the stronger is the tie. According to Inkpen (2000, p.1027), trust “reflects the belief that a partner’s word or promise is reliable and that a partner will fulfil its obligations in the relationship”. Therefore trust may significantly support a more personal relationship and strengthen a tie.

³Although research widely argues for a positive relationship between trust and transfer of knowledge, studies by Lane *et al.* (2001) and Yli-Renko *et al.* (2001) indicate that high levels of trust may as well inhibit knowledge exchange.

Chinowsky *et al.* (2010) recognise that a network approach and the concepts of trust and communication begin to surface in terms of engineering and construction projects. The University of Colorado developed a social network model for construction that respects factors as trust or shared values. Chinowsky *et al.* (2010) state that the connection of a social network perspective and trust integrates the findings from traditional research in facilitators of information or knowledge transfer and social dynamics.

Because there is overwhelming evidence that trust enables the transfer of information between individuals, this study chooses to establish a trust relation \mathcal{X}_3 . The definition of relation \mathcal{X}_3 that investigates the trust between network members is shown in Table 3.2. Trust is not necessarily reciprocated, therefore its measurement shall be directed. The numeration is chosen as binary because a definition of strength of trust is exceptionally philosophical and sensitive.

Table 3.2: Trust relation.

| \mathcal{X}_r | Relation | Structural Variable / Survey Question | Attribute(s) |
|-----------------|----------|---------------------------------------|---------------------|
| \mathcal{X}_3 | Trust | Whom do you trust? | Content & Direction |

3.7 An Approach for the Analysis of Decision Making

SNA distinguishes itself from other research approaches by a number of principles. Wasserman and Faust (1994) clarify that the network models view the network's structural environment as providing opportunities and constraints for individual action. For the application in this thesis individual action may be *decision making*.

Research in utilising SNA to investigate decision making received some attention. In addition, past research also reveals a number of factors that compromise effective decision making. Dahl (2005) employs SNA to assess the relative power of agents in making key decisions, as opposed to the power as a correlate to formal position. Work by Krackhardt and Hanson (1993) is another example of an attempt to incorporate SNA in order to aid decision making. A variety of work by Cross *et al.* (2001, 2002a, 2006, In Press), Cross and Thomas (2010), Norton (2010) and the "Network

Roundtable”⁴ affirms abilities of informal networks to disclose constraints in effective decision making. Exemplary, Cross *et al.* (2002a) demonstrate that people with a highly central position in an informal network may have disproportionate influence on information traffic and decision making. The identification of such key roles may help managers to allocate decision rights and increase effectiveness of a group. Latest research by Cross *et al.* (In Press) look more closely at how SNA can be applied in order to assess and streamline decision making interactions in companies. A network perspective can yield substantial insight in decision making dynamics. Exemplary, SNA unveiled that employees compellingly sought support for making decisions. Decision making was pushed up the hierarchy and senior managers were found to be unintentional decision blockers. SNA may depict the dynamics in decision making and point towards a lack of clarity in roles, responsibilities, authority and empowerment.

3.7.1 Analytical Scope

The research community discovers many reasons for failure in decision making. Cross *et al.* (In Press) present a selection of causes for decision making failure. Amongst others, problem areas include team composition, ineffective leadership, failed group processes, overconfidence, cognitive biases and many more⁵. In this thesis the approach rests upon a network perspective and the relational aspects of decision making. The matter of interest is how the fabric of informal networks influences how decisions are forged and put into effect. The analysis is dissociated from problem areas beyond a network perspective.

Cross-functionality necessitates decision effects to cross organisational boundaries. This troubles clear accountabilities and may impose collaborative demands in decision making, which are difficult to manage. On the one hand the outcome may be a network dominated by excessive collaborative action in spinning agreements that paralyse decision processes. On the other hand, educated decision making might require the expertise of colleagues; making consultation between functional areas a necessity. SNA can not judge the quality of decisions but might expose the problem areas of unclear decision rights and slacking or excessive collaborative decision processes. Investigations concerned with the quality of decisions are outside the scope of this thesis. Rather, the intent of this study is to elucidate the informal dynamics: *who* relies on advice and approval from *whom* in making decisions.

⁴The Network Roundtable is a user community that combines contemporary real-world business applications and academic research to advance network analysis and its applications in corporate, public and non-profit institutions. More information regarding the community can be accessed at www.thenetworkroundtable.org

⁵References for further reading are provided in Cross *et al.* (In Press, p.27-29).

3.7.2 Relations of the Decision Making Network

Unclarity or uncertainty in decision making may lead individuals to make enquiries about supplementary advice or approval. Receipt of approval or advice in decision making involves exchange of some non-material resource. The strategy of inquiry has to harness means against redundancies. Fundamentally, it is important to ensure that the *content* of the measured relations is distinct. This gives reason for the SNA to narrow the exchange of supplementary information to its specific role in decision making. Therefore, the content of relation \mathcal{R}_4 and \mathcal{R}_5 is defined as advice and approval in decision making, respectively.

Table 3.3: Relations of decision making.

| \mathcal{R}_r | Relation | Structural Variable / Survey Question | Attribute(s) |
|-----------------|--|---|---------------------|
| \mathcal{R}_4 | Advice in decision making | Who do you typically rely on for advice prior to making decisions? | Content & Direction |
| | Strength of decision advice reliance tie | How often do you typically approach this person regarding advice in decision making? | Strength |
| \mathcal{R}_5 | Approval in decision making | Who do you typically rely on for approval in decision making? | Content & Direction |
| | Strength of decision approval reliance tie | How often do you typically approach this person regarding approval for decision making? | Strength |

Ties are directed because the reliance of one person on another involves a direction and a reciprocity of any such relationship can not be assumed. In congruence with this argument, Marin and Wellman (2011) state that ties of advice seeking are directed. The frequency of interaction accounts for the *strength* of the relational tie in both relations. The decision making relations and corresponding survey questions are shown in Table 3.3. Alternatively to frequency, the intensity or strength of a relationship may be expressed as the quantity of traded resources. It is problematic to specify an “amount” of advice or approval that has been exchanged. Therefore, the amount of time that is spent in decision making interactions may be used as a proxy. This method is applied by Cross *et al.* (In Press). However, it is contended that a frequency of interaction is easier to recall and implies a smaller burden on research participants. Therefore this thesis employs a measure of interaction frequency to account for tie strengths.

For relation \mathcal{R}_5 some assumptions have to be stated at this point. Firstly, it is assumed that the organisational hierarchy governs decision rights. That is, it is expected that arcs point up the hierarchy and no arc should point down from a higher rank to a lower rank. Approval for decision making is provided by individuals positioned “higher” in the organisational hierarchy for those individuals that are positioned “lower” in the organisational hierarchy. Secondly, decision rights are assumed to be allocated to a single individual. Decisions are not made in a group. It is assumed that the network does not contain any actor pairs that are connected by bidirectional arcs, a so called cycle between actors. The network of relation \mathcal{R}_5 is expected to be *acyclic*, thus the network does not include any *cycles*.

3.8 Conceptualisation of Survey Methodology

The previous sections elucidate the preliminaries for a SNA application, the social network study design, its boundaries and approaches that construct informal networks of information flow and decision making. The theoretical framework of the SNA application is laid out and the survey questions for data collection are established. That is, Phase 4 of the application methodology is to follow. In the following section the means for the collection of network data are presented.

Marsden (2005) says that network studies draw extensively on survey and questionnaire data. Surveys and interviews collecting social network data ask respondents to report to whom they share particular relations. The following sections discuss the survey methodology and the details of data collection. It is proceeded by discussing the actor identification, sampling methods and concerns regarding validity, reliability, accuracy and error in network data. On the basis thereof, decisions regarding the data collection technique are made. Moreover, this section makes considerations regarding human subject protection and draws the attention to strategies for gaining commitment of research participants. The conceptualisation of the survey methodology closes with the presentation of the questionnaire design.

3.8.1 Actor Identification

Scott (2000) says that unless the population under investigation is very small, some kind of enumerated list that covers the whole target population may be required. Based on the network boundary, organisational records and the consultation of managers an organisational chart is supplemented with contact details and used as the baseline for the data collection process. Thus, yielding a *fixed-list* of the *relevant* actor set. According to Marsden (2005, 2011), the creation of a roster of actors before engaging in data collection is common practice for whole network studies.

3.8.2 Network Sampling

Marsden (2011) states that network surveys rarely employ sampling methods. Wasserman and Faust (1994) and Marsden (2011) concur that most network studies involve a well-defined, completely enumerated set of actors, rather than samples of actors of a larger population. The boundary for this study has been framed elaborately and the data collection procedure is assumed to enumerate all *relevant* actors. According to Scott (2000), few sampling problems arise in network studies involving a small set of actors, where it is generally possible to record the entirety of relevant actors. On the contrary, research on large scale social systems entail particular intractable sampling problems⁶. Wasserman and Faust (1994) commend Ove Frank as the most widely known and most important researcher in network sampling methods. In multiple publications; he presents the basic and more advanced solutions to network sampling⁷ problems. This thesis does not attempt to make inferences on the network structure of populations other than the particular network under investigation. This leads this thesis to assume that the relevant actors in this study have been recorded in their entirety and that the application of network sampling methods is unsuitable.

3.8.3 Data Quality

Marsden (1990, 2005, 2011) discusses numerous sources of error in survey data of social networks. The author also reviews the respective research in these areas. Marsden (2011, p.381) clarifies that the available data quality studies “do not yield a single or unambiguous verdict about the quality of survey measures of networks.” Alwin (2007) and Marsden (2011) show that quality assessments for network data are population specific and any specific findings are more suggestive than definitive. It is not in the interest of this thesis to exhaustively consider all methodological research. Rather, the influential lines of research and salient concerns with regard to the case studies in this thesis shall be highlighted. The following sections enable the application methodology to forestall potential sources of error in survey data by targeting a survey design that anticipates quality survey data and raises awareness for the limitations of the chosen approach.

Reporting Accuracy and Data Validity

Validity of a measure describes the success in actually measuring what is intended to measure. The research by Feld and Carter (2002) suggests that validity of survey

⁶Methods in network sampling are presented in Wasserman and Faust (1994, p.33-34) and by Frank (2011, p.389-403).

⁷Wasserman and Faust (1994, p.34) provide a broad selection of Ove Frank's work. For the common method of snowball sampling, see Frank (2005).

measures may be dependent on the network properties that are recalled. They refer to this effect as the “expansiveness bias”. Brewer (1995) finds that perceived *social proximity* appears to govern recall of persons. That is, respondents are expected to give advantage to recalling alters so that they maintain a more intimate relationship to such actors that are “closer” to them.

Wasserman and Faust (1994) show that there is a considerable body of research regarding informant accuracy. Important works are summarised by Bernard *et al.* (1981). Primarily, research concludes that people are not very accurate in reporting their interactions in particular situations. A different line of research by Freeman, Romney and colleagues (for example Freeman and Romney (1987) and Freeman *et al.* (1987)) finds that measurement errors in survey reports of past social interactions are *biased toward long-term* patterns. Hence, survey respondents are able to report stable patterns of social interaction validly rather than retrieving particular situations with precision. Hammer (1980, 1985) postulates that particular interactions are not the major concern of social network researchers. It is the more stable patterns of interaction that are the major concern. Therefore, it has to be considered that the SNA is likely to capture more stable habits of interactions than the actual interaction state at one point of time. This also urges this investigation to consider a lead time before the survey can capture the changes in interaction patterns.

In Marsden (2005) it is pointed towards the fact that whole-network studies ask respondents to only report on *direct* relationships. Accordingly, researchers implicitly take data that is collected from each individual actor to be more valid than the data recorded from third party-informants. This view is also practiced by this thesis. Data is solely collected on each respondents’ direct relationships and survey participants are not asked to report on the relationships of their peers.

Data Reliability

Measures of a variable are reliable if repeated measurements deliver the same estimates. Wasserman and Faust (1994) briefly outline methodological problems and assessments methods. Although it is difficult to draw general conclusions from the present research it is worthwhile noting some findings. Research by Marsden (1990) and Hammer (1985) suggests that responses to more intense or intimate relations have higher reliability. Marsden (2011) shows that these findings are confirmed by a number of further studies. Therefore, the network data on the relationships of trust is expected to be especially reliable. This also puts emphasis on the use of valued relational data from a methodological point of view. The presence of more intense, stronger ties may be more reliable than that of weak ties. Burt *et al.* (1985) show

that the reliability of aggregate measures (such as popularity) is higher than the reliability of individual actor recalls.

Measurement Error

Measurement error describes the discrepancy between the “true” value of a concept and the observed value. As argued by Holland and Leinhardt (1973), the social ties collected by SNA research may differ from the present structure of relational ties. Brewer (2000) elucidates that using rosters simplifies the reporting task for respondents by reminding them of eligible actors within the network. Using lists limits measurement error due to forgetting by respondents, therefore Brewer (2000) advises to make preferable use of recognition, rather than recall when possible. This holds an argument for initiating the survey process using a fixed list. Contrary, Holland and Leinhardt (1973) state that measurement errors can originate in a fixed choice data collection designs because this implies a certain number of choices that might not be appropriate in the case of particular respondents, therefore inducing error. This concern is shared by Marsden (2011), the author shows that measurement errors can arise from limited choices. On one hand, limiting the amount to a certain number of citations reduces the burden on respondents by simplifying and specifying the sociometric task. On the other hand, limited choices can induce “false negatives” (a respondents number of ties actually exceeds the limit of choices set by the researcher) or “false positives” (respondents are encouraged to choose additional alters in order to reach the choice limit). Consequently, measurement errors may be decreased by providing an enumerated list of actors and by not limiting the amount of possible citations by survey participants.

As mentioned under reporting accuracy, measurements tends to be biased toward long term patterns of social interactions. Apart from this, Marsden (2011) says that errors may also be attributable to nonresponse. The author concludes that all research data contains errors and this raises legitimate concerns about the survey approach. Nevertheless, its strengths that are often attributed to the flexibility of the method should not be forgotten. Albeit, it has to be noted that the data collection in this thesis only involves four distinct frequencies of interaction that determine tie strength: *hourly*, *daily*, *weekly*, *monthly*, see Section 3.8.5. Inevitably, these fail to describe the “true” interaction habits between actors. Nevertheless, the aim is to achieve an approximation of interaction. Rather than to determine the real habits of actors. The chosen approach serves its purpose and consciously induces measurement error in the data collection.

3.8.4 Data Collection Technique

Social network data can be gathered using a variety of techniques. Amongst others, Wasserman and Faust (1994, p.45) list questionnaires, interviews, observations, archival records and experiments. For the purpose of this thesis, data is collected through a survey using questionnaires. According to Wasserman and Faust (1994) this technique is the most commonly used and most useful when actors are people and the studied relations can be best identified by the actors themselves; this is the case for the application of SNA in this thesis. Marsden (2005) further outlines that surveys are often the most practical alternative as they make much more modest demands on participants than other methods do.

There are different formats that can be used to design a questionnaire. It can be decided to present a roster of identified network members to each actor, or to allow each network member to freely recall his or her relations (fixed list vs. free recall). The researcher may also limit the number of relations that each network member has to indicate (free choice vs. limited choice). In some studies network members are asked to rank order or rate all other actors in the set. The fixed list method and the expanding selection method are presented in Section 3.5. At the core, the fixed selection method has some advantages. This method is cheaper to administer, is less prone to error and provides far fewer data processing problems. This advocates using a fixed list to collect data. However, Marsden (2011, p.372) criticises that reviewing names from a large roster can be a “cumbersome, tedious task” for respondents.

Doreian and Woodard (1992) point out that the fixed list and expanding selection approaches are distinct and generally do not yield the same networks. Networks from the fixed list method are smaller and contain fewer ties. The fixed list captures the core of a network. The pitfall of solely using a fixed list is that the procedure fails to capture the periphery structure of a network, its structural context. This argument is enforced by the studies of Sudman (1985) and Hlebec and Ferligoj (2002), which show that recognition methods yield larger networks. Marin and Wellman (2011) and Wasserman and Faust (1994) argue for a free recall of further network members by already identified network members, if a network is very large or no complete list of the network is available. Other arguments for the use of expanding selection coexist⁸ but are of minor importance to the network study in this thesis.

Prior to data collection a fixed list of actors is identified on the basis of the boundary specification and organisational records. The prepared list is then present-

⁸A more detailed discussion opposing the fixed list and expanding selection procedures is presented by Doreian and Woodard (1992).

ted to the identified actors. They are given the opportunity to indicate interactions to actors that are included in the list or to add additional actors to the list by freely recalling them. This thesis makes use of an expanding selection procedure and does not limit the number of choices. This decision rests upon four main arguments. Firstly, there might be a periphery of actors that are not included in the documents from which the fix list is derived. As mentioned in 3.5, consultants or contractors are one example, they are not included on the organisational chart and would methodologically and mistakenly be excluded from the study. Secondly, it is argued that the use of a fixed list may limit measurement errors due to “forgetting”. In the third place, the use of a fixed list is expected to simplify the reporting task for respondents. Lastly, the number of choices is not limited in order to avoid measurement error by implying false-negatives and false-positives.

3.8.5 Questionnaire Design

The questionnaire in this thesis is designed to measure whole network data in one-mode networks. The questionnaire aims to assign a value to each relationship x_{ij} between the actor i and j with $i \neq j$ for each relation \mathcal{R}_r . Therefore, the questionnaire asks each research participant i to identify the actors j with whom a relationship is maintained. Using the expanding selection method, respondents can choose actors from a fixed list as well as freely recall additional actors. Subsequently, the surveyed individual is also asked to indicate the respective (typical) frequency of interaction for each choice (with exception of relation \mathcal{R}_3). In consideration of the suggestions by Marsden (2011), the measurement design refrains from using “vague quantifiers” (for example “often” or “rarely”) and favours commonly understood measurement units. The predefined interaction frequencies are: *hourly*, *daily*, *weekly* and *monthly*. Interactions that occur less than once a month are assumed to be insignificant. The reliability on such weak relationships may also be questionable. The corresponding line values are assumed to be direct proportional to a month consisting of four weeks. Each week is assumed to have five working days, of which each has eight working hours. The corresponding line valuing is shown in Table 3.4. Based on the selection made by i , a value v_i is assigned to x_{ij} . An excerpt from the developed questionnaire is shown in Table 3.5. An overview of all questionnaires that have been designed for this study is provided in Appendix E.

Each indication by a respondent is of a binary type. According to Marsden (2005), binary judgements are the least difficult for respondents while ranking tasks are more demanding. The Indication of tie strength is of ratio scale. A combination of binary selection and quantitative attributes measure on ratio scale is used because

Table 3.4: Line value assumptions.

| <i>Tie strength</i> | <i>Value v_i</i> |
|---------------------|-------------------------------|
| Monthly | 1 |
| Weekly | 4 |
| Daily | 20 |
| Hourly | 160 |

Table 3.5: Questionnaire excerpt.

| SECTION A | | SECTION B | | | |
|--|-------------------------------------|---|-------------------------------------|--------------------------|--------------------------|
| Who do you typically receive work related information from? (At least on a monthly basis) | | How often do you typically receive work related information from this person? | | | |
| | | Hourly | Daily | Weekly | Monthly |
| 0 Example | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 1 Mike Johnson | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 2 Elisabeth Brown | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 3 Adriaan Marais | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| ... | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

research participants first complete the less straining binary selection to indicate alters they maintain relations to. The more burdensome selection of the tie strength is thus only applicable to the selection of actors that have already been identified. The questionnaire makes exclusive use of binary choices and minimises the writing task. It is assumed that this is an easily understood procedure and eases survey completion for research participants. Apart from this, Marsden (2011) states that recall methods must ensure the unique identification of alters. Therefore research participants are asked to recall alters with both, their first names and surnames.

3.8.6 Human Subject Considerations

Marsden (2011) highlights that SNA researchers are obligated to protect research subjects against harms arising from disclosure of research data. It has to be ensured that any risks to research subjects is minimal and outweighed by potential

research benefits. Surveys collecting social network data must comply with all laws, regulations and norms that govern the conduct of survey research. Citro (2010) clarifies that amongst others this involves obtaining voluntary, informed consent from respondents, minimising risk to them and protecting their confidentiality after data are assembled and research reports are handed out. The research ethics are respected and appropriate participant consent forms are issued as part of the data collection process. The respective consent form for the network survey is provided in Appendix C. An application for conducting the research has been submitted to the Stellenbosch University Research Ethics Committee and received approval in May 2012. The corresponding approval documentation is attached in Appendix D.

The above outlines the necessary measures in order to comply with the conduct that governs survey research. One of the main purposes of the consent form is to inform each research participants about the subject, intent, implied risks and potential benefit of the SNA research project. Informing research participants about the essential elements of the study and their involvement in the study is not only a necessity. Müller-Prothmann (2006) emphasises that the active and continuous communication to all parties that are involved in the SNA application are highly important to reach successful results. The author enumerates a number of recommendations for the communication to survey participants that draw on the insight from psychology:

- Provide information and make all involved parties sensible for the SNA.
- Articulate the relevance and importance of the SNA.
- Produce personal concern for and reduce reservations against the SNA
- Produce straightforward actions.

At the heart of these steps lies the aim to create personal involvement and the willingness to participate among research participants. Apart from this, Müller-Prothmann (2006) points towards the key role of middle managers in this process. Accordingly, every manager plays an important role as a disseminator of information and creator of involvement of his or her subordinates. Producing straight forward actions entails the removal of technical barriers. It has to be ensured that after personal involvement and the willingness to participate is reached; the survey process is not obstructed by technical aspects such as the accessibility of questionnaires.

The adequate information of all parties that are involved in the SNA may contribute to a successful SNA application. In achieving this, the informed consent

form (see Appendix C) and well as the support my managers may play a crucial role. Therefore, these factors shall find adequate consideration during the SNA application at research sites.

3.9 Network Properties and Structural Calculations

The previous section established the theoretical framework for a SNA application and enabled the collection of empirical SNA network data at a research site. Informal networks that represent information flow and decision making in PAM can be constructed. In the final Phase 5 of the SNA application methodology a variety of measures to examine the created networks are presented.

In SNA a wide range of metrics can be calculated. The methods of network analysis provide explicit formal statements and measures of structural properties. Hanneman and Riddle (2011*b*) and De Nooy *et al.* (2011) outline that network analysts and graph theorists have developed a large number of formal algorithms to analyse the network structure. Of the many structural features that have been quantified, some pertain to the entire network and others concern subnetworks and individual actors. The concepts of various network measures are presented by Scott (2000), Wasserman and Faust (1994), Scott and Carrington (2011) and De Nooy *et al.* (2011). Wasserman and Faust (1994) explain that the selection of the approach is dependent on the collected data and the aims of the analyst. De Nooy *et al.* (2011) add, that while it is more concise and precise to explore a network by calculation than by visual inspection, network metrics may be abstract and difficult to interpret. Therefore, a combination of structural indices and visual examination is expedient. The provided definitions are consistent with the concepts in Wasserman and Faust (1994), Scott (2000) and De Nooy *et al.* (2011).

3.9.1 Cohesive Subgroups

Cohesion describes the fact of forming a united whole. In network terms, this means that numerous, relatively strong, direct, intense, frequent or positive ties among actors make an actor subset more cohesive. A cohesive subgroup is a subset of actors who are more tightly connected than the remainder of actors in a set. Consider a plant, where a strong silo mentality is present. The engineering and production department may be largely disconnected but internally very cohesive. An analysis for cohesive subgroups may reveal the functional silos. Wasserman and Faust (1994) point out that the identification of cohesive subgroups or actors is one of the major concerns in network analysis. Network analysts promote a number of techniques to determine cohesion and detect cohesive subgroups.

Density

Scott (2000) describes density as one of the most widely used concepts in SNA. Density is understood as the general level of linkage among actors within a network. De Nooy *et al.* (2011) state that more ties between actors yield a tighter structure, which is, presumably, more cohesive. In accordance with De Nooy *et al.* (2011), *density* is the number of lines in a network, expressed as a proportion of the maximum possible number of lines. A graph is called complete if the network achieves the maximum density, then each point is directly connected to every other point. According to Wasserman and Faust (1994, p.129), the density for a directed graph Δ is formally defined as the number of arcs L , expressed as a proportion of the maximum possible number of arcs ($g(g - 1)$), see Equation (3.1).

$$\Delta = \frac{L}{g(g - 1)} \quad (3.1)$$

This perspective of density refers to unvalued graphs and disregards line values. Scott (2000) emphasises that density is a problematic measure to use with valued data and that there is little agreement about how density should be measured in valued graphs. One option is to disregard line values and to transform lines into a binary form. However, this involves a significant loss of information. A second option is to weigh the number of lines with their respective values or strengths. The denominator, the maximum possible number of lines is then represented by the product of possible relational ties and the highest possible line value. This figure is then based upon specific assumptions about the maximum possible value of a line. The valued density may be calculated with Equation (3.2).

$$\Delta^V = \frac{\sum x_{ij}}{v_{\max} \cdot g \cdot (g - 1)} \quad (3.2)$$

Network Size

The *size* of a network is is very important and can be expressed as the number of nodes within a network. Hanneman and Riddle (2011*b*) explain that size is critical for the structure of social relations because actors only have limited resources and capacities for building and maintaining ties. Hence, with increasing network size the density is expected to decrease. That is, the density of a network is dependent on network size. Scott (2000) mentions that this dependence prevents density measures from being comparable across networks that vary significantly in size. The density measures in this study will be highly sensitive to the assumptions above. Valued densities are totally incommensurable with network studies that vary in study design.

Hanneman and Riddle (2011*b*) clarify that density and size of a network merely give an indication of potential social structures that may be present in a network. The network's structure is much more significant and a number of metrics can be applied to analyse its patterns.

Degree

Density is a problematic measure for cohesion because it is dependent on network size. A better opportunity to investigate cohesion is offered by the concept of *degree*. De Nooy *et al.* (2011) explains that the nodal degree $d(n_i)$ is the number of lines that a node is incident with. Wasserman and Faust (1994) make clear that for a directed graph a node can be either adjacent to, or adjacent from another node. The difference in “outgoing” and “incoming” lines is quantified and expressed as *indegree* and *outdegree* of a node. If a node has a degree equal to zero it is called an *isolate*. Wasserman and Faust (1994) explain formally: the indegree of a node n_i is equal to the number of arcs in the form of $l_k = \langle n_j, n_i \rangle$. Thus, the outdegree of a node n_i is the number of arcs in the form of $l_k = \langle n_i, n_j \rangle$. Accordingly it is defined:

The *indegree* of a node, $d_I(n_i)$ is the number of arcs terminating at n_i .

The *outdegree* of a node, $d_O(n_i)$ is the number of arcs originating at n_i .

The higher the degree of vertices, the more dense a network is connected. Therefore, the average degree of a network is a good means of assessing structural cohesion. It is a more advantageous measure as the density because it is independent of the network's size. Consequently, degree values are comparable across networks. In order to measure the average degree in a directed network, the network has to be symmetrised. Symmetrising a network means that all unilateral and bidirectional arcs are turned into edges. However, an average indegree and outdegree may be calculated supplementary.

Components

A disconnected graph may be partitioned into two or more subsets of nodes. Wasserman and Faust (1994) explain that the connected subgraphs in a graph are called components. According to Scott (2000, p.101) a *component* is formally defined as a “maximal connected subgraph”. The author further explains that a subgraph is “connected” when all its nodes are linked to one another through lines; all points in a connected subgraph can “reach” each other through one or more lines. Maximal connected means that no nodes can be added to the subgraph and it still retains

its quality of connectedness. A simple example of a disconnected graph with two components is shown in Figure 3.5.

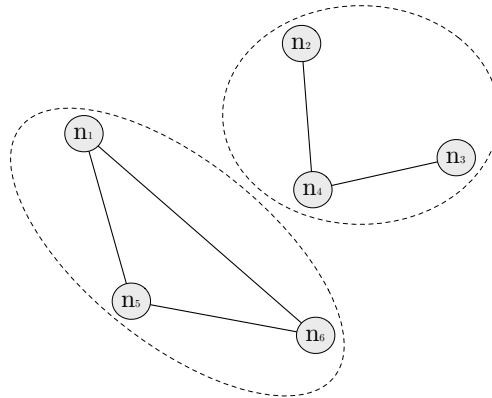


Figure 3.5: Disconnected graph with two components.

Scott (2000) further explains that for directed graphs two distinct types of components exist: *strong components* and *weak components*. In order to define the components for directed graphs the important concepts of *walk*, *semiwalk*, *paths* and *semipath* have to be defined. This thesis adopts the definitions as outlined by De Nooy *et al.* (2011, p.77-78):

A *semiwalk* from node n_i to n_j is a sequence of lines such that the end node of one line is the starting node of the next line and the sequence starts at node n_i and ends at node n_j .

A *walk* is a semiwalk with the additional condition that none of its lines are an arc of which the end node is the arc's tail.

A *semipath* is a semi walk in which no node in between the first and last node of the semiwalk occurs more than once.

A *path* is a walk in which no node in between the first and last node of the walk occurs more than once.

Thus, semiwalk and semipath neglect the direction of arcs, while walk and path obey to the constraints imposed by an arc's direction. De Nooy *et al.* (2011) note that one might say that a path is more efficient than a walk, because it does not pass through one node more than once. Therefrom, the definitions for a strongly and weakly connected network (often it is just called connected) can be derived. A (*weak*) *component* and *strong component* are defined as follows:

A network is (*weakly*) *connected* if each pair of nodes is connected by a semipath.

A network is *strongly connected* if each pair of nodes is connected by a path.

A (*weak*) *component* is a maximal (weakly) connected subnetwork.

A *strong component* is a maximal strongly connected subnetwork.

Geodesic Distance

A simple measure of “reachability” is the *average geodesic distance* between two nodes. The shortest *path* between two nodes is called the *geodesic*. The *geodesic distance* $d(n_i, n_j)$ between node n_i and n_j is the length of the geodesic, expressed as the number of lines, from n_i to n_j . Logically, the average geodesic distance is determined by equation (3.3).

$$\bar{d}(n_i, n_j) = \frac{\sum d(n_i, n_j)}{g} \quad (3.3)$$

3.9.2 Brokerage

In network analysis it is argued that ties to people, who are not related themselves, generally yield more useful information than ties to individuals that are themselves related. De Nooy *et al.* (2011) explain that ties within a group expose actors to a single pool of information, whereas ties that transcend the group can access a greater diversity of information. Apart from this, actors with ties to different groups could mediate between groups and realise benefits thereof. Actors whose ties connect people who are themselves not directly connected, bridge so called *structural holes*. Structural holes are rooted in the absence of ties that leverage an individuals control over others and create opportunities for exploitation. It is postulated that bridging structural holes awards an actor with mediating power and control over others.

The ties that are indispensable for keeping a network connected are called *bridges*, a node that is necessary for a network to remain connected is called a *cut-vertex*. The removal of a bridge or cut-vertex increases the number of components of a network. When a network contains bridges or cut-vertices the resource flow is susceptible for disruption and the network contains potential bottlenecks.

3.9.3 Centrality and Centralisation

Centrality and centralisation were two of the earliest concepts to be pursued by network analysts. *Centrality* refers to an actors position in a network, while *centralisation* refers to properties of the graph structure as a whole. Measures of centrality

and prestige highlight prominent actors in a network. Wasserman and Faust (1994) state that important or prominent actors are typically found in strategic valuable locations within the network. Van Wijk *et al.* (2008) argue that while the number of ties increases access to resources, a centralised⁹ position determines whether the resources can be used beneficially. Central actors have better access to the resources that are transferred throughout a network and their position leverages their ability to spread resources through the network themselves.

Granovetter (1982) clarifies that SNA views the way in which an actor is embedded in a network as imposing opportunities *and* constraints in an actors actions. Hanneman and Riddle (2011*b*) explain that the core idea of centrality is that actors who are more "central" to social structures are more likely to be influential or powerful. However, these actors may also be more constrained. Consider an information exchange network at a plant that includes one electrical foreman that is also exceptionally experienced in the field mechanical and boilermaker tasks. Additionally, this foreman is known for his responsiveness to requests. A great number of other foreman may approach this actor for supplementary information or advice in making decisions. On the one hand, the experienced foreman takes a strategically important position in the network to spread resources. On the other hand, the high number of approaches towards him constrain him in a sense that they significantly draw on the actors working time at the plant. As a result, the actor may maintain fewer ties to actors from different organisational functions than the engineering department, eventually constraining his or her ability to acquire cross-functional information. The implications of a central network position are twofold.

Centralisation measures quantify the variability of individual actor centrality. The measures investigate whether a network consists of actors with very high centrality and actors with very low centrality, or if the network has a moderate, more evenly distribution of actor centrality. In terms of the foreman example this can be interpreted as follows: a plant either contains a small number of highly authoritative foremen in highly central positions, or resource exchange interactions are more evenly spread across the entirety of the plant's foremen.

Network analysts developed a variety of different approaches to determine centrality and centralisation. The following views and means to analyse centrality and centralisation are confined to undirected and unvalued networks. Their presentation is a necessity in order to introduce the concepts for directed networks, notably prestige. Although the measures of centrality might not be of as much concern

⁹This statement is not valid for degree centrality which is, in fact, based on the number of ties.

for directional networks as measures of prestige, Wasserman and Faust (1994) recommend calculating both measures since the structural properties they attempt to measure are distinct. The various measures of centrality and centralisation are based on different ideas of what constitutes centrality. Degree and closeness measures are based on the idea that actors are central if information may easily reach them, the concepts are based on a approach of “distance”. Betweenness centrality is based on the idea that an actor is more central if he or she endues a position as strong intermediary in the network. Eigenvector centrality follows the approach of distance, but suggests that the centrality of an actor is determined by the centrality of the actors he maintains ties with. Prestige is based on the idea that an actor is prominent if he receives many choices by others.

Scott (2000) explains that a number of competing concepts lead to proliferation of formal measures and considerable confusion in the area. In order to to avoid confusion, this thesis chooses to refer to the consensus view of concepts as outlined in Wasserman and Faust (1994) and De Nooy *et al.* (2011).

Degree Centrality and Degree Centralisation

Wasserman and Faust (1994) argue that the simplest way to determine centrality is by defining central actors as the most “active” in terms of maintaining ties with other actors. De Nooy *et al.* (2011) suppose that an actor with more ties has greater access to resources. Wasserman and Faust (1994, p.178-180) define: the *degree centrality* $C_D(n_i)$ of a node is its degree $d(n_i)$. Equation (3.5) shows how the degree centrality can be standardised for different network sizes using its maximum value $g - 1$. An actor with a large degree is directly adjacent to numerous other actors. The actor is in direct contact with many network members and should be recognised as a major channel of relational information. Actors with low degrees take a peripheral position in the network, they are not as involved in the relational process.

$$C_D(n_i) = d(n_i) \quad (3.4)$$

$$C'_D(n_i) = \frac{d(n_i)}{g - 1} \quad (3.5)$$

The centralisation of a network indicates the spread of centrality among actors. When a network is highly central, then several actors might maintain a highly centrality, while others remain in the periphery of a network maintaining a very low centrality. De Nooy *et al.* (2011) elucidate that a network is more centralised if its nodes have greater variations of centrality. Accordingly, the *degree centralisation* of

a network is the variation in the degrees of nodes divided by the maximum degree variation that is possible in a network of the same size:

$$C_D = \frac{\sum_{i=1}^g [C_D(n^*) - C_D(n_i)]}{\max \sum_{i=1}^g [C_D(n^*) - C_D(n_i)]}, \quad (3.6)$$

with $C_D(n^*)$ being the largest observed value of $C_D(n_i)$. Freeman (1979) shows that the denominator of this index can be calculated directly and equals $(g-1)(g-2)$, this yields

$$C_D = \frac{\sum_{i=1}^g [C_D(n^*) - C_D(n_i)]}{[(g-1)(g-2)]} \quad (3.7)$$

Closeness Centrality and Closeness Centralisation

Another view of centrality is based on the closeness of actors; in other words, on the distance between actors. Wasserman and Faust (1994) state that the idea behind closeness centrality is that actors are central if they can easily interact with all others. The measure assesses the reachability of nodes by length of interaction paths. The *closeness centrality* of a node is the number of other nodes divided by the sum of all geodesic distances between the node and all other nodes:

$$C'_C(n_i) = \frac{g-1}{\left[\sum_{j=1}^g d(n_i, n_j) \right]} \quad (3.8)$$

The *closeness centralisation* of a network is the variation in the closeness centrality of nodes divided by the maximum variation of closeness centrality that is possible in a network of the same size. According to Freeman (1979) the maximum possible variation of closeness centrality is given by $[(g-2)(g-1)]/(2g-3)$.

$$C_C = \frac{\sum_{i=1}^g [C'_C(n^*) - C'_C(n_i)]}{[(g-2)(g-1)]/(2g-3)} \quad (3.9)$$

with $C'_C(n^*)$ being the largest observed value of $C'_C(n_i)$.

Betweenness Centrality and Betweenness Centralisation

Two non-adjacent actors might depend on other actors in order to interact. Wasserman and Faust (1994) say that the actor “between” other, not connected actors might

have some control over the interaction. As De Nooy *et al.* (2011) explain, the approach of betweenness centrality values centrality in terms of the intermediary role of an actor and the question of how crucial an actor is to the transmission of resources through a network. Accordingly, De Nooy *et al.* (2011, p.150) say “the centrality of a person depends on the extent to which he or she is needed as a link in the chains of contacts that facilitate the spread of information within the network.” The *betweenness centrality* of a node $C_B(n_i)$ is defined as the proportion of all geodesics g_{jk} between two nodes that include the node n_i .

$$C_B(n_i) = \sum_{j < k} g_{jk}(n_i) / g_{jk} \quad (3.10)$$

The *betweenness centralisation* is the variation in the betweenness centrality of nodes divided by the maximum variation in betweenness centrality scores possible in a network of the same size. Freeman (1979) shows that the maximum possible variation in betweenness centrality is given by $\left[(g-1)^2 (g-2) \right] / 2$.

$$C_B = \frac{2 \sum_{i=1}^g [C_B(n^*) - C_B(n_i)]}{\left[(g-1)^2 (g-2) \right]} \quad (3.11)$$

Eigenvector Centrality

The measure of eigenvector centrality was originally introduced by Bonacich (1972). Bonacich (2007) explains that while degree measures weigh each actor equally, *eigenvector centrality* weighs each contact according to its own centrality. That is, the measure is based on the assumptions of degree centrality but suggests that that an actor is especially central if he is adjacent to actors that have a high centrality themselves; “it is important to have contacts, but it matters whom you know”.

There is circularity inherent to the calculation of the measure. To calculate the score of a node n_i , the centrality of its neighbours and the neighbours of those has to be calculated, which includes actor n_i again. This problem is solved arithmetically using eigenvalues and eigenvectors. Let \mathbf{X} be the $g \times g$ adjacency matrix for an undirected graph $\mathcal{G}(\mathcal{N}, \mathcal{L})$ and x_{ij} the binary elements of the adjacency matrix. Golub and Loon (1983) showed that because \mathbf{X} is symmetrical all its eigenvalues are real, its eigenvectors are orthogonal and it is diagonalisable. Eigenvector centrality can be described in two equivalent ways, as a matrix equation and as a sum. Bonacich (2007) shows that the eigenvector centrality e_i of a node is proportional to the sum of the centralities of the nodes to which it is connected.

$$\lambda e_i = \sum_{j=1}^g x_{ij} e_j, \quad i = 1, \dots, g \quad (3.12)$$

Defining the vector of centralities $\mathbf{e} = (e_1, e_2, \dots, e_g)$, it can be written:

$$\lambda \mathbf{e} = \mathbf{X} \cdot \mathbf{e} \quad (3.13)$$

Newman (2008) explains that assuming the centralities to be non-negative, using the Perron-Frobenius theorem it can be shown that λ must be the largest eigenvalue of the adjacency matrix \mathbf{X} and \mathbf{e} the corresponding eigenvector.

The above assumptions do not hold for the study design in this thesis. Even though the valued numeration will be neglected for the calculation of eigenvector centrality, the directed nature of the network shall be retained for the analysis. Symmetrising the networks defined on relation \mathcal{X}_4 are \mathcal{X}_5 results in a considerable loss of information, this is disallowed.

In order to identify important actors in a directed network on the premise of eigenvector centrality, De Nooy *et al.* (2011) employ the algorithmic tools developed by Kleinberg (1999). The author proposes a link-based model for the conferral of authoritative information and a consistent identification of authoritative information in a hyperlinked environment (exemplary the World Wide Web). At the very basic, the method differentiates between entities as *authorities* and *hubs*. Hubs point to many “good” authorities of a certain topic and good authorities are entities that are pointed to by many hubs. Kleinberg (1999) explains that hubs and authorities are characterised by a *mutually reinforcing relationship* and that some method is required in order to break the circularity of the approach. The proposed solution to the problem is an iterative algorithm that maintains and updates numerical non-negative *authority weight* $x^{(n)}$ and *hub weight* $y^{(n)}$ for each actor n_i . For the purpose of this thesis and the directed networks it investigates this algorithm will be employed. For a comprehensive explanation of the iterative process it is referred to Kleinberg (1999).

3.9.4 Prestige

Prestige is a structural concept and related to the measures of centrality. According to the distinctions drawn by Knoke and Burt (1983), centrality and prestige are measures of an actors prominence in a network. Contrary to the measures of centrality, the concept of prestige specifically refers to directed networks. Wasserman and Faust (1994) and De Nooy *et al.* (2011) concur that a *prestigious* actor is one who is a *recipient* of many ties. Thus, the prestige of an actor depends on the number of

ties that are directed towards the actor. The ties that are initiated by the actor may be disregarded. There is little consensus regarding centralisation measures involving the concept of prestige. Therefore, centralisation measures are not discussed.

Degree Prestige

The simplest measure of prestige is measured by the number of arcs directed towards a node: a nodes indegree $d_I(n_i)$, also termed its *popularity*. As outlined by Wasserman and Faust (1994) this measure is dependent on network size and may be standardise with $g - 1$ giving:

$$P_D(n_i) = d_I(n_i) \quad (3.14)$$

$$P'_D(n_i) = \frac{d_I(n_i)}{g - 1} \quad (3.15)$$

Proximity Prestige

De Nooy *et al.* (2011) point out that degree Prestige or popularity is a limited measure of prestige, because it only takes notice of direct sociometric choices. The so called input domain contributes to advancing the concept of prestige. The input domain counts direct and indirect linkages. The *input domain* I_i of a node in a directed network is the number of nodes that are connected by a *path* to this node. The input domain includes all actors that can reach n_i .

Proximity prestige accounts for how proximate actor n_i is to the actors in its input domain, it weighs each linkage by its path distance to the node n_i . Higher distance contributes less to the proximity prestige. According to De Nooy *et al.* (2011), the *proximity prestige* of a node is the proportion of all other nodes in its input domain divided by the mean distance from all nodes in its input domain. In accordance with Wasserman and Faust (1994), the proximity prestige $P_P(n_i)$ is calculated by dividing the standardised input domain by the average distance from all nodes in the input domain:

$$P_P(n_i) = \frac{I_i/(g - 1)}{\sum d(n_j, n_i)/I_i} \quad (3.16)$$

It can be seen that a larger input domain (larger numerator) or smaller average distance (smaller denominator) yield a greater proximity prestige. A smaller proximity prestige is achieved vice versa.

3.9.5 Roles and Positions

The properties of *social roles* and *social positions* are concerned with the analysis of actors' structural similarities and patterns of different relations. Although the analysis methods are mathematically and formally diverse they share a common goal. Wasserman and Faust (1994) explain that every approach aims to expose subsets of actors on the basis of the pattern of how they are embedded in the network. For this thesis, it is important to distinguish between positions that exist by assumption of organisational hierarchy and positions that spring from the analysis of tie structures.

Ferligoj *et al.* (2011) remark that within organisations certain positions exist within its social structure (commonly a hierarchy). These formal positions are coupled into a system of roles consisting of different responsibilities. For a plant, a formal position can be understood as performing as a maintenance engineer or the plant manager. The particular position is connected to a role or role set that involves different tasks and social connections. The engineer may consult fellow engineers and instruct subordinates how to maintain machinery, while the manager may be in touch with the accounting or human resources department. It is assumed that a particular *position* is connected to a set of *roles* and equates to a distinct pattern of ties.

Ferligoj *et al.* (2011, p.434) explain that key empirical issues in position and role analysis involve "delineating positions in social systems, identifying roles that correspond to these positions and the nature of and extent to which these roles exist." According to Wasserman and Faust (1994) two foundational approaches to positional and role analysis exist. Firstly, identifying social positions as collections of actors who are similarly embedded in the network (positional analysis) and secondly, the modelling of social roles as systems of ties between actors or positions (role analysis). For this thesis, it is not the intent to conduct a full positional and role analysis that groups actors and describes the associations among relations. Furthermore, it is not the aim to model the ties between positions and the system of relations among actors. This thesis limits itself to the first approach, namely to a positional analysis. This approach can be considered typical. Wasserman and Faust (1994) explain that most analyses focus on similarities of actors and pay less attention to the relations among the positions. The authors acknowledge that there is much to gain from the analysis of structural similarities on its own.

An actors position in this analysis is two faced. On the one side, the actor's position is governed by the formal job description which dictates his activities within the organisational network. On the other side actors represent a position in the network

that relies on the analysis of relational data. The crux of the matter is to ferret deviations between the *formal* position and the exercised *informal* position. The aim is to oppose and compare the present tie structure around positions (across different relations) to that, formally expected by occupation. In PAM it may be beneficial to investigate the informal roles in a decision approval network. A positional analysis can deliver insight where the informal roles significantly deviate from formal roles. One possible reason could be that individuals do not comply with the formal decision processes, thus inducing unclarity of decision rights or causing ineffectiveness of decision making.

Wasserman and Faust (1994) state that a positional analysis requires consideration of the tasks shown below. Since probability models of networks fall outside the scope of this thesis and it is focused on exploratory methods, it is desisted from performing step iv.

- i. A formal definition of equivalence.
- ii. A measure of the degree to which subsets of actors approach that definition in a given set of network data.
- iii. A representation of the equivalences.
- iv. An assessment of the adequacy of the representation.

Equivalence

The equivalence definition in this thesis is based on *structural equivalence*. Actors are said to be structurally equivalent¹⁰ when they exhibit a similar structure of ties. For the purposes of this thesis, structural equivalence is defined in line with the classical paper of Lorrain and White (1971) and the view stated in De Nooy *et al.* (2011). Two actors are structurally equivalent if they have identical ties with each other and all other actors.¹¹ However, it may be noted that different mathematical concepts exist that constitute “identical” ties.

Measure of Structural Equivalence

In applying a measure of structural equivalence, it is important to note how definitions and computation algorithms apply to the characteristics of relations. For every relation \mathcal{X}_r , the corresponding data set conforms to the following conditions:

¹⁰De Nooy *et al.* (2011) remark that in other texts actors are said to be relationally equivalent, constitute an equivalent class or take equivalent positions.

¹¹This definition does not account for loops because these have no practical application in the network study design of this thesis.

- The data set will be treated as having a *dichotomous* numeration.
- The directionality of the data set will be retained as *directed*.
- Loops are not allowed. Due to the research design the *diagonal values* of all sociomatrices for the relations \mathcal{X}_r are *zero*.

The main reason for disregarding line values is that the distinction of structural similarity is problematic using the defined tie strengths. A single difference in a sociometric choice may account for a substantial difference of the line value to a shared neighbour. Based on this argument the $g \times g$ dissimilarity matrix $\mathbf{D} = \{d_{ij}\}$ is computed using the dissimilarity measure $d_1(i, j)$ presented by Batagelj and Mrvar (2011). The measure assesses the normalised number of neighbours that are not shared by the two actors i and j :

$$d_1(i, j) = \frac{|N_i + N_j|}{1\text{st maxdegree} + 2\text{nd maxdegree}} \quad (3.17)$$

where $+$ stands for symmetric sum¹² and $|$ stands for cardinality¹³. Batagelj *et al.* (1992) present a number of advanced algorithms that consider line values for dissimilarity computation. These are considered to be problematic because they are very sensitive to differences in line values.

Representation of Informal Position

Informal positions are represented in dendrograms. The major goal of the dendrogram representation is to present the network data in a simplified form and to provide an interpretable form of results. The equivalence classes that spring from the positional analysis are represented in a *dendrogram* using a method of *hierarchical clustering*. Hierarchical clustering is a data set technique for partitioning actors into positions. Wasserman and Faust (1994) explain that among other methods, this particular one is ideally suitable. Numerous texts and methods exist in hierarchical clustering. Generally, the methods group entities into subsets based on a criterion of their similarity. The method is called hierarchical because it successively uses less restrictive distinction criteria to define clusters. Thus, the method successively joins clusters until eventually only a single cluster exists. For the clustering of positions the *Ward*¹⁴ method of hierarchical clustering is employed.

¹²A symmetric sum is any sum in which any permutation of the variables leaves the sum unchanged.

¹³The cardinality of a set is a measure of the number of elements of the set.

¹⁴The Ward clustering method is explained in great detail in Batagelj (1988)

3.9.6 Blockmodelling

Previous techniques compute structural measures that are focussed on the individual actor. In contrast, blockmodelling groups actors into clusters and investigates the relationships between the clusters. Although blockmodelling is a technique that can measure different structural concepts it is emphasised that the technique does not replace the structural measures that have been outlined. In blockmodelling, analysis results are depicted by the permutation¹⁵ of adjacency matrices.

De Nooy *et al.* (2011) explain that blockmodelling is used in network research projects to illuminate the informal structure of actor positions in the network. For the purpose of this thesis the application of blockmodelling are diverted from their original use. Hanneman and Riddle (2011*b*) argue that the texture of networks can be affected by “categorical social units” that are defined by shared attributes or context. On the assumption that the network is structured on the basis of an organisational hierarchy a block model is obtained by permuting adjacency matrices according to department classes that are derived from organisational records. On the basis thereof, a block model can be used to assess the relationships between organisational functions (blocks), rather than modelling a network structure by derivation from the informal organisation. In PAM, a blockmodel may specifically be used in order to investigate the cross-functional relations between the different departments that “run” a plant. Blockmodelling may reveal organisational silos, particular cross-functional reliances or lacking collaboration between functions. A *block* contains the cells of a permuted adjacency matrix that belong to the cross section of one or two classes (also termed positions) \mathcal{B}_α and \mathcal{B}_β . The structure of a network within and between positions, can be described by analysing the blocks. The cohesion within and between blocks is specified by the valued block densities as shown in Equation (3.18) and (3.19). The block density reflects the total utilisation of all possible ties between two blocks. Block densities for binary network data are determined analogous, with $v_{\max} = 1$.

$$\Delta_{\mathcal{B}_\alpha \rightarrow \mathcal{B}_\alpha}^V = \frac{\sum x_{ij}(\mathcal{B}_\alpha \rightarrow \mathcal{B}_\alpha)}{v_{\max} \cdot g(\mathcal{B}_\alpha) \cdot (g(\mathcal{B}_\alpha) - 1)} \quad (3.18)$$

$$\Delta_{\mathcal{B}_\alpha \rightarrow \mathcal{B}_\beta}^V = \frac{\sum x_{ij}(\mathcal{B}_\alpha \rightarrow \mathcal{B}_\beta)}{v_{\max} \cdot g(\mathcal{B}_\alpha) \cdot g(\mathcal{B}_\beta)} \quad (3.19)$$

At the very basic, Equation (3.20) yields the proportion of resources that are traded in each block. Apart from that, it may be interesting to look at the proportion of which a class provides resources to other classes, see Equation (3.21).

¹⁵A permutation of a network or matrix is a reordered or sorted network by renumbering of vertices. Correspondingly, a permutation is a renumbering of vertices.

$$P_{\mathcal{B}_\alpha \rightarrow \mathcal{B}_\beta} = \frac{\sum x_{ij}(\mathcal{B}_\alpha \rightarrow \mathcal{B}_\beta)}{\sum x_{ij}} \quad (3.20)$$

$$p_{\mathcal{B}_\alpha \rightarrow \mathcal{B}_\beta} = \frac{\sum x_{ij}(\mathcal{B}_\alpha \rightarrow \mathcal{B}_\beta)}{\sum x_{ij}(\mathcal{B}_\alpha \rightarrow \mathcal{B}_k)} \quad (3.21)$$

It has to be borne in mind that the measures are dependent on block size. Notwithstanding, the measures deliver some indication of how tightly the respective classes are connected to each other and what share of the interaction by each class is allotted to each block. The methods of blockmodelling are the final network measures that is considered by the application methodology. In the following, the chapter summary summarises the methodological decision that have been made throughout the sections above.

3.10 Chapter Summary

The aim of Chapter 3 is to develop a SNA application methodology that is capable of assessing the primary constraints in PAMSE in terms of information flow and decision making. For this reason, Chapter 3 establishes five application phases that, when completed, enable the application of SNA in PAM environment. The five phases are outlined at the outset of this chapter and repeated below:

- Phase 1: Application Preliminaries
- Phase 2: SNA Design and Boundary
- Phase 3: Constructing Networks
- Phase 4: Collecting Data
- Phase 5: Analysing Networks

Phase 1 clarifies the aim and field of the application and chooses the unit of observation for the SNA. After that, Phase 2 outlines the SNA study design and defines the study boundaries. In Phase 3, analysis approaches to information flow and decision making are developed. Furthermore, Phase 4 presents a survey methodology, suitable for collecting social network data. Considerations regarding data quality influence the data collection technique. In addition, considerations regarding the protection and commitment of survey participants are made. Phase 5 completes the SNA application methodology. In this step, a number of network properties and structural calculations are presented that govern the exploratory analysis of networks.

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Chapter 3 discusses each methodology phase against the background of publications in SNA. Consequently, the methodological decisions, which are supported by leading texts about SNA, serve the purpose of the stated application aim. Amongst others, the application methodology is based on Wasserman and Faust (1994), Scott (2000), Scott and Carrington (2011) and De Nooy *et al.* (2011). The methodological decisions, regarding the SNA application in PAM, are referred to throughout the chapter. For the convenience of the reader, Tables 3.6, 3.7 and 3.8 provide an abridged summary of the application methodology and the most important decisions. To summarise, Chapter 3 develops a sound SNA application methodology which allows for the exploration of the informal networks of information flow and decision making in PAMSE. The fifth research objective of this theses is achieved.

Chapter 1 showed that the means to detect primary constraints in PAMSE are deficient. Moreover, the chapter identified SNA as a possible solution to the stated problem. Chapter 2 contextualised the problem components and the proposed solution. In addition, the chapter singled out information flow and decision making as the primary constraints in PAMSE and demonstrated that SNA may be capable of investigating these problem areas. The literature review gave clarity to the fundamental reason for a SNA application in PAM. Chapter 3 expanded on the findings of previous chapters and developed a comprehensive SNA application methodology in order to investigate informal networks of information flow and decision making in PAM. The next research objective of this thesis is to apply the developed SNA application methodology at a suitable research site. This is the focus of Chapter 4.

In Chapter 4, the developed SNA application methodology is utilised at two research sites in the the South African mining industry. The case studies investigate SNA as a method to map primary constraints in PAMSE and yield an array of valuable results.

Table 3.6: SNA application methodology Phase 1, 2 and 3.

| <i>Section / Step</i> | <i>Key Decisions</i> |
|----------------------------------|--|
| Phase 1: Preliminaries | |
| 3.2 Aim of application | The aim of the SNA application is to map primary constraints in the domains of information flow and decision making in PAMSE. |
| 3.3 Field of application | Asset-centric organisations. |
| 3.3 Unit of observation | Individuals who are involved in PAM at a plant of the studied asset-centric organisation. |
| Phase 2: SNA Design and boundary | |
| 3.4 SNA Study design | Whole network approach. Multiple one-mode networks are created. Analysis involves one compositional variable that captures an actor's occupation. The SNA is of exploratory nature. Study design does not allow for loops. |
| 3.5 Network boundaries | Hybrid of normalist and realist perspective. Application of the expanding selection methodology. |
| Phase 3: Constructing networks | |
| 3.6 Information flow | Relation \mathcal{X}_1 of information exchange; measurement Level 4. Relation \mathcal{X}_2 of PAM information exchange; measurement Level 4. Relation \mathcal{X}_3 of trust; measurement Level 3. |
| 3.7 Decision making | Relation \mathcal{X}_4 of advice in decision making; measurement level 4. Relation \mathcal{X}_5 of approval in decision making; measurement Level 4. |

Table 3.7: SNA application methodology Phase 4.

| <i>Section / Application Step</i> | <i>Key Decisions</i> |
|-----------------------------------|---|
| Phase 4: Collecting data | |
| 3.8.1 Actor identification | Creation of a fixed-list of the relevant actor set on the basis of study boundary, organisational records and consultation of managers. |
| 3.8.2 Network sampling | Not required. It is assumed that all <i>relevant</i> actors for the study are captured. No inferences on a larger population are made. |
| 3.8.3 Data quality | Network data is biased by the expansiveness bias. Network data is biased towards the long term and stable patterns of relationships. Data is only collected on direct relationships. Stronger ties and aggregate measures may be more reliable. Consider occurrence of false negatives and false positives if choices are limited. Conscious induction of measurement error due to predefined interaction frequencies of tie strengths. |
| 3.8.4 Data collection technique | Collection of social network data using a survey method. Creation of a fixed (actor) list according to the boundary definition. Use of the expanding selection methodology. Actors are enabled to freely recall other actors. Fixed list is provided to actors in order to limit “forgetting”. Measurement errors due to false negatives and false positives are avoided by not limiting choices. |
| 3.8.5 Questionnaire design | Vague quantifies for tie strengths are avoided by using commonly understood time units as hourly, daily, weekly, monthly. Tie strengths of an interaction frequency less than monthly are insignificant. Lines are valued according to Table 3.4. The questionnaire blueprint is shown in Table 3.5. Use of binary indications to minimise burden on survey participants. Unique identification of freely recalled actors by requesting first and surnames. |
| 3.8.6 Human subject protection | Conduct of survey research is considered. Informant consent forms are provided, see Appendix C. Approval for the study by the Stellenbosch University Ethics Committee is obtained, for approval notice see Appendix D. It is important to create commitment among participants. |

Table 3.8: SNA application methodology phase 5.

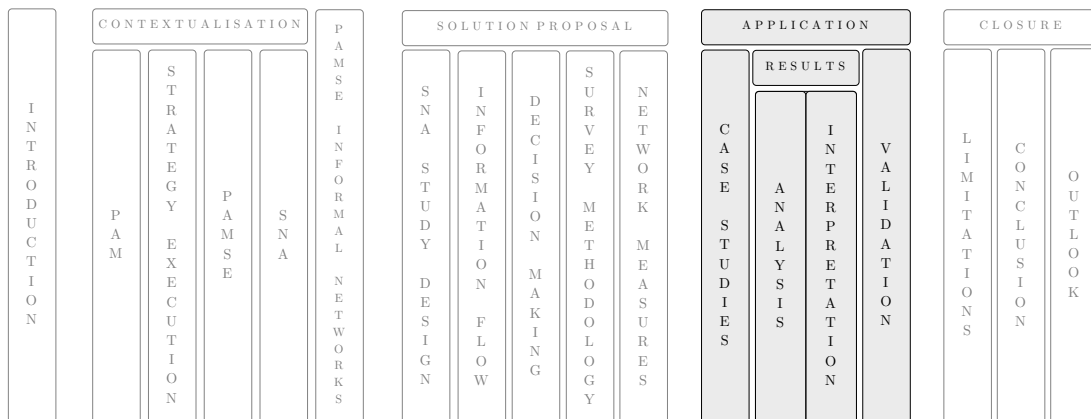
| <i>Section / Application Step</i> | <i>Key Decisions</i> | |
|-----------------------------------|-------------------------------|--|
| Phase 5: Analysing networks | | |
| 3.9 | Visual inspection | Inaugural visual inspection of the network is expedient. |
| 3.9.1 | Cohesive subgroups | Assessment of the network's overall cohesion. Identification of locally tighter connected subsets of actors. Essential concepts: Density, network size, degree and components. Use of the average geodesic distance as a measure of "reachability" between actors. |
| 3.9.2 | Centrality and centralisation | Identification of prominent actors within a network; actors that are in a strategically important network position. Different approaches to centrality are applied: Degree centrality, closeness centrality, betweenness centrality, eigenvector centrality, degree prestige, proximity prestige. Centralisation measures quantify the variability of individual actor centrality. Measures include the degree centralisation, closeness centralisation, betweenness centralisation. |
| 3.9.5 | Positional analysis | The structural equivalence of actors is assessed and opposes informal roles to formal role definitions on the basis of the organisational hierarchy. Hierarchical clustering is done using the Ward method. Representation of results in dendrograms. |
| 3.9.6 | Blockmodelling | Actors that belong to a department are grouped. The adjacency matrix is permuted according to departmental classes. Each "block" in the permuted adjacency matrix represents the relationships between two departments or with a department. Inter- and intradepartmental relationships are assessed using the block model and presented measures. |

Chapter 4

Case Studies

Chapter Aim:

The aim of this chapter is to utilise the previously developed SNA application methodology in two case studies in order to detect primary constraints in PAMSE.



Chapter Outcomes:

- Introduction to SNA application preliminaries.
- Introduction of case studies.
- In depth exploration of case study networks.
- Discovery of primary constraints in PAMSE.
- Validation of results.

4.1 Getting Started

Chapter 2 found that deficient information flows and decision making are the primary constraints in successful PAMSE. Chapter 3 developed a comprehensive SNA application methodology in order to explore the informal networks of these salient problem areas. Being equipped with means to explore the informal networks of information flows and decision making, Chapter 4 utilises the developed methodology, applies it at two suitable research sites and tests the capability of SNA to elucidate the primary constraints in PAMSE. The execution of the developed SNA application methodology is facilitated in cooperation with two asset-centric organisations. Each case study is abbreviated by the first capital letter of the respective cooperating organisation. Therefore, the case studies are abbreviated with Case Study *R* and *A*, respectively. Chapter 4 boils down to the application of SNA in the two cases in order to explore the method's ability to map primary constraints in PAMSE.

Before embarking upon the analysis of the case studies, it is important to outline the essential preliminaries, these involve the process of approaching research partners, the agreement on a study boundary, the resulting changes to the application methodology and the required assumptions to the analysis.

The first step towards research cooperation is to obtain sponsorship from senior management of adequate organisations. Therefore, senior managers are familiarised with the intent of this thesis and the benefit that can spring from the research; if a SNA can be applied successfully. At this point it is important to point out that the research partnership with organisations necessitated modifications to the SNA application methodology. It is important that these modifications are considered and are clearly stated while the presentation of these modifications are deferred to the following section 4.2. After a consensus of methodological modifications has been reached and an organisation agrees to host the network study; it is decided upon the network boundary and employed survey method according to the recommendations from senior management and the resources available to the researcher. While the boundary for the network study firstly depends on the research participants' formal employment at the studied organisation; it gets tightened around actors that are sufficiently involved in PAM. In agreement with senior management, the departments and individuals that are most applicable to the investigation are purposefully selected. Before the survey methodology finds application at the research site, a small group test of the survey methods is performed. Survey preparations and data collection were engaged in June 2012.

In the following section the required modifications to the SNA application methodology are introduced. Subsequently, the thesis introduces the necessary assumptions that provide the framework for the analysis of case studies. The presentation of assumptions rounds the network study framework and the analysis of case studies is engaged. The case studies are presented one after another, beginning with Case Study *R* and successively presenting Case Study *A*.

4.2 Methodological Modifications

The cooperation with organisations gives rise to two adjustments of the SNA application methodology. In the interest of the cooperating organisations; this thesis adapted to the following methodological modifications:

- (1) The implementation of a structured PAM framework, such as PAS 55, is pursued by both research partners. It may be noted that the organisation in Case Study *R* appears to be more mature in the implementation process. Management in Case Study *A* acknowledge that the implementation process is still in its infancy. In spite of the different implementation states of the senior engineering managers of both research partners point out that a conceptual understanding of PAM is largely absent throughout the organisation. Therefore, relation \mathcal{R}_2 was expected to only create confusion under the research participants. Consequently, relation \mathcal{R}_2 is unfeasible for both case studies and was thus excluded from the survey.
- (2) Relation \mathcal{R}_3 raised considerable concern of research partner *R*. The research site experiences problems of organisational culture and management found that surveying trust would impede the initiatives for cultural change and improvement. The intent to survey the trust among employees significantly hindered the approval process for the study. Trust may be a facilitator for social interaction and of some theoretical importance. In order to accommodate certain sensitivities of the cooperating organisations and to promote a positive research partnership; relation \mathcal{R}_3 has been excluded form the investigation in *both* case studies.

4.3 Assumptions

The application of SNA in PAM practice requires the definition of a number of assumptions. Empirical data is seldom perfect and induces an error in the analysis if complications are not considered. Moreover, it is considerably naive to believe that *every* factor that conducts the dynamics within the actor set can be incorporated or grasped by the analysis. Instead, reasonable assumptions are necessary to frame

the analysis and ground its argumentation. Assumptions are subdivided into *general* assumptions that overarch both case studies and *specific* assumptions that are applicable to one specific case study only. Specific assumptions are introduced side by side with the respective case study.

General Assumptions:

- (1) The organisation pursues a strategic goal for the management of physical assets.
- (2) Strategic goals are achieved through PAM initiatives.
- (3) Formal positions and responsibilities are defined by the hierarchy of the organisation.
- (4) The survey captures every actor that is *relevant* for the scope of the study.
- (5) Structural measures are taken on the network consisting of the subset of actors on which relational data is collected.
- (6) Subnetworks have a minimum size of three nodes. Compartmentalised nodes that do not form a subnetwork are isolates.
- (7) The research design does not allow for loops or multiple lines in any network.
- (8) Despite blockmodelling, analyses are confined to relational data of binary numeration.
- (9) Actors can be clustered according to their affiliation with an organisational department or function.
- (10) Approval for decisions does not get passed on between individuals. Approval for a decision is represented by direct ties only.
- (11) Networks of relation \mathcal{R}_5 are acyclic.

4.4 Case Study *R*: Rio Tinto

Case Study *R* was conducted in cooperation with a minerals mining company located in South Africa. The company is primarily managed and owned by the British-Australian multinational mining corporation Rio Tinto Plc and its operations are highly dependent on the functionality of mining machinery and process infrastructure. Physical assets are of paramount importance to the organisation.

The company's physical asset and reliability management are a centralised and combined function. For the survey, the reliability and asset management, as well as the engineering and production functions have been selected. It is contended that they are the most appropriate actors for the study because physical assets and strategic initiatives in the management, thereof, are central to their activities. Therefore, the selected survey participants range from senior management to the mines engineers, superintendents, maintenance controllers, planners, specialists in reliability engineering and technicians in condition monitoring. Due to the company's location and implied travel expenses a personal administered survey is excluded. In coordination with senior management it has been decided to administer the survey using a Microsoft Excel spread sheet and distributing it through email, rather than using online based data gathering platforms. The main reason is that on-site internet access is limited and every participant can be expected to be Microsoft Excel literate. The data collection process was engaged in July 2012.

4.4.1 Data Processing

The survey for Case Study *R* contains a fixed list of 58 actors that have been identified on the basis of organisational records and the consultation of different managers. The survey did not achieve a sufficient return rate of questionnaires. In fact, only 27.6% of all prospective survey participants completed the questionnaire. On average the questionnaire completion required 11.33 minutes. The figure is based on 12 returned questionnaires. Four respondents failed to make a correct indication of the editing time.

The assumption that every *relevant* actor was captured by the survey does not hold for Case Study *R*. Too little data was obtained on the informal network at the research site. In line with the majority of network studies, this investigation focusses on a well defined actor population and the methodology in this thesis does not incorporate probabilistic sampling for networks. It has to be acknowledged that no adequate data was obtained for Case Study *R*. The data that is available on the network is not usable in connection with the developed SNA application methodology. Consequently a SNA for Case Study *R* can not be conducted and was discontinued.

4.4.2 Commentary

This section reflects on the barriers that have been experienced during the research process and provides practical examples of potential set backs to employing SNA.

Rio Tinto was approached in February 2012. Although the organisation intended to cooperate in facilitating a SNA, the approval process was stagnant. This was mainly because no one took the responsibility to formally approve or decline the study proposal. The decision of approving the study was passed on between individuals and the process lost momentum. As a result, the approval process was stalled in the beginning of April 2012. Towards the end of April 2012, the research ambitions were elevated to the organisation's executive management. After sponsorship was obtained from a senior manager, the study process was revived. The next hurdle in the research process was to obtain records that reflect the current organisational structure. In several cases, organisational records were out dated, but after repeated consultations all relevant actors were enumerated. In a next step, the SNA study was promoted by management by informing the staff about the study and asking for participation. Questionnaires were issued in early July 2012. After more than four weeks a response rate of merely 27.6% was achieved; in spite of the fact that senior management informed participants about the study and asked for their participation, and an additional "reminder" was sent to every non respondent. Due to the non response of study participants it was decided to discontinue the study in the beginning of August 2012.

Despite the fact that the SNA in Case Study *R* failed, a number of considerations and results emerge that shall not be held back. Müller-Prothmann (2006) highlights, that it is essential to create motivation among employees by building an understanding of the analysis and the benefit of participation. Further, the author highlights the important role of managers as promoters for the study inside the studied organisation. Most fundamentally, the Case Study *R* confirms these factors as determinants for the success of a SNA application.

The study approval process in Case Study *R* illustrates that an application of SNA demands a cooperating individual with the authority and courage to drive the project. The SNA survey requires the personal involvement of survey participants, the study process and benefit have to be carefully coordinated with the responsible management of each functional unit. Presumably, survey participants are best informed and motivated by an active personal involvement of the researcher. However, with growing actor population and geographically distant research sites, this process becomes very resource intensive. In Case Study *R* an education of research participants could only be provided using email. This may have been insufficient in order to reach a sufficient level of commitment by survey participants and may have contributed to the failure of the SNA application.

Section 4.2 outlines that Case Study *R* experiences problems of organisational culture. The success of a SNA application may also rely on a participative research environment and open minded research subjects that willingly engage in the study. If the organisational culture is not supportive and employees feel insecure or even threatened when data is collected on them, the SNA application may be at risk. A problematic organisational culture in Case Study *R* may have lowered the commitment of research participants additionally, causing the data collection to stall.

Case Study *R* puts forwards that unless management and research participants are motivated and actively engage in the research process, the SNA may fail at the data collection stage. However, this may require the active and personal involvement of the researcher as an energetic advocate for the benefits of a SNA. On the basis of the findings from Case Study *R*, it is confidently believed that *energetic senior sponsorship*, a *supportive organisational culture* and the *adequate motivation of employees* are the most important prerequisite for the success of a SNA application, ideally the researcher should advocate the SNA *personally* at the research site. In Case Study *R*, these prerequisites were only partly given, presumably leading to the failure of the SNA application. The findings from Case Study *R* echo concerns stated in Müller-Prothmann (2006).

4.5 Case Study A: Anglo American Platinum

Case Study *A* was conducted in cooperation with Anglo American Platinum Limited (AAPL). AAPL is a subsidiary of the British multinational mining company Anglo American plc. and the world's largest producer of platinum, delivering about 40% of the world output. Presently, platinum mining operations are jeopardised by a second steep decline of the platinum price since 2008. During the 2008 economic crisis, platinum prices plummeted from about US \$2,000 per ounce to prices of US \$900. After the market recovered steadily reaching prices of US \$1,800 in mid 2011; it experienced a steep decline during the last year. Current prices of about US \$1,450 per ounce demand drastic cost savings from platinum mining organisations and sharpen their focus on the efficiency of operations.

The research site of investigation is an AAPL concentrator operation located in the company's South African "Bushveld Complex". The operation is highly dependent on the function of mining machinery and process infrastructure; the performance of physical assets is indispensable for achieving the operational targets. Despite the current economic challenges, the plant under investigation is determined to expand its operations and production output. Currently, the research site faces two major

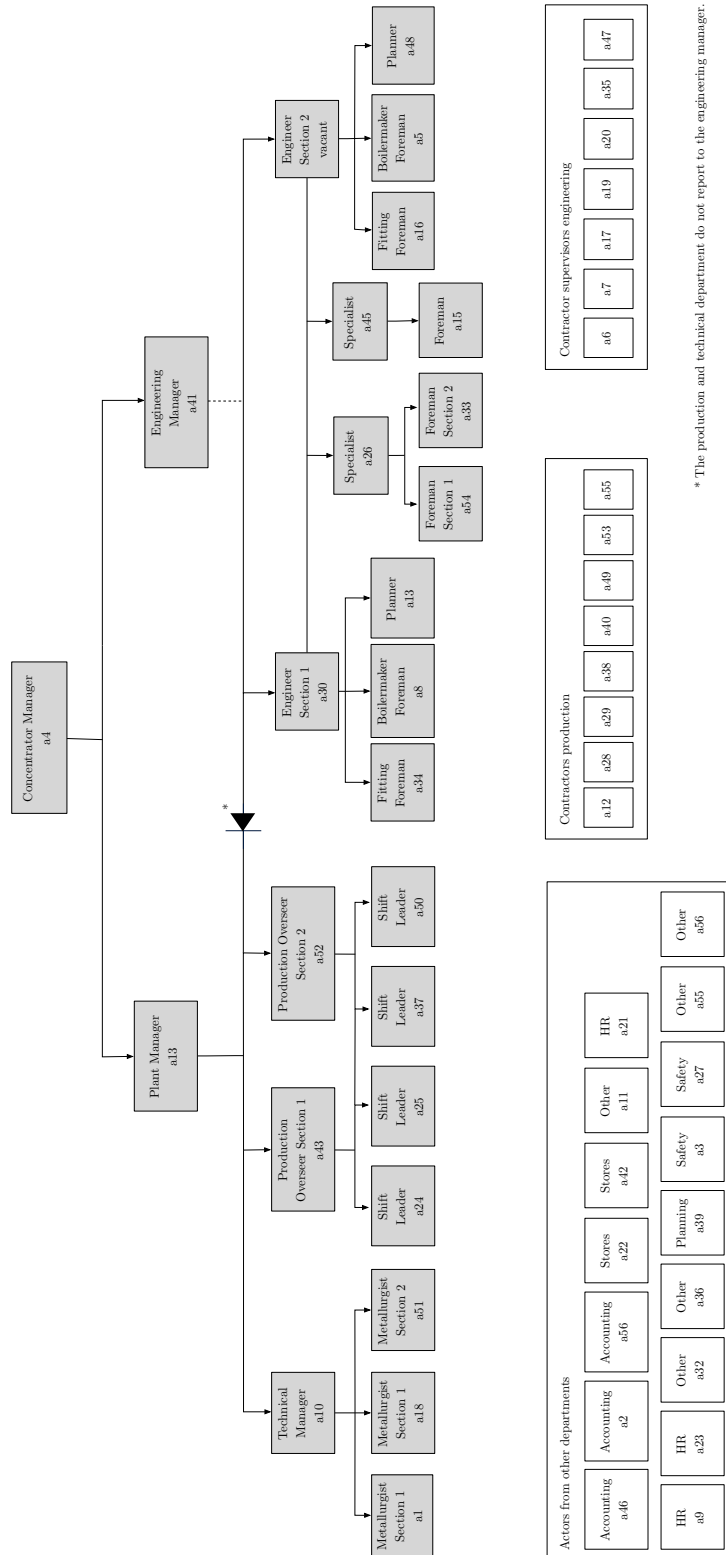
strategic initiatives that rest on the management of physical assets. The initiatives are an expansion and de-bottlenecking project that attempt to significantly increase the capacity of the operation. The research site does not have a departmentalised PAM function. At present, the management of physical assets is not seen against the background of a formal management framework (e.g. PAS 55), yet. However, senior management put forward that the implementation of a PAM framework has been initiated and is eagerly strived for. At present, strategic PAM initiatives in PAM are executed through the existing organisational structure, shown in Figure 4.1. The boundary for the case study was set around the concentrator's management and essential functional areas. These include the technical-, engineering- and production department. Therefore, survey participants encompass the concentrator management, the respective department's middle management, production shift leaders, engineering specialists, engineering foremen as well as the metallurgists from the technical department.

The research project received considerable support from AAPL and was conducted in collaboration with the Asset Care Research Group (ACRG)¹. Consequently, the survey was administered personally at the research site in June 2012. As a result, every research participant was informed personally about the research process and the potential benefits that spring from a SNA application. In this way, an appreciation and considerable support for the study was established with research participants. However, it has to be pointed out that the organisational culture supported the research ambitions. In general, research participants were very eager to not only improve the performance of the plant but to improve their personal performance. It appears that the staff's morale is driven by collaboration as team and that it is eagerly strived for improvement.

4.5.1 Specific Assumptions

- (1) The product production process is single stream and is divided into two sections.
- (2) The organisational hierarchy corresponds to Figure 4.1.
- (3) Responsibilities of the engineering department are divided according to process sections one and two.
- (4) Actor a15, a26, a45 are involved in section one *and* two of the process.
- (5) The position of the section engineer for section two is vacant.

¹The ACRG acts as an intermediary to facilitate interactions on aspects related to PAM between industry and the University of Stellenbosch. For further information please refer to <http://www.ie.sun.ac.za/acrg>.



* The production and technical department do not report to the engineering manager.

Figure 4.1: Organigram Case Study A.

- (6) PAM optimisation projects are lead by an member of the technical department and facilitated in collaboration with the engineering department.
- (7) The actors a37 and a44 are off-duty since three and five months, respectively.
- (8) The six engineering contractor supervisors have 52 subordinates.

4.5.2 Data Processing

Survey data of Case Study *A* relies on a fixed list containing 25 actors who have been identified using organisational records. Using the expanding selection method, a maximum network size of 56 actors was achieved in the case of relation \mathcal{X}_1 . For every freely recalled actor a job position was identified. On average, survey participants required 16.2 minutes to complete the questionnaire. The average is based on 17 survey participants that indicated the editing time correctly. Eight participants failed to make a usable indication on the survey form. A questionnaire return rate of 100% was achieved. That is, every *relevant* actor has been surveyed, the general assumption (4) holds and network sampling methods are not required.

The questionnaire data (the questionnaire is attached in Appendix E) has been digitalised, inputted into an adjacency matrix, anonymised and then analysed using the software packages “Pajek”, “Matlab” and “Microsoft Excel”. A variety of procedures have been followed to apply structural measures on the data sets and render suitable visual representations. Network graphs have been drawn using the algorithm developed by Kamada and Kawai (1989). The arrangement of nodes does not imply results from any measure. Where considered advantageous, the graph structure has been modified.












4.5.3 Analysis and Interpretation

Network centralisation measures on a single network are problematic. The analysis results are not interpretable without the calculation of reference measures from comparable networks. Adequate reference vales for each relation could neither be acquired from a database nor could a second case study be used to produce reference values (see following section). Therefore, centralisation measures are solely applied to compare networks of different relation and are based on the indegree $d_I(n_i)$.

At the outset of the analysis every actor is classified as part of a partition that reflects his or her formal position in the organisational hierarchy. The resulting departmental classes \mathcal{B}_k and their respective colour key are shown in Table 4.1.

The analysis attempts to follow a generic procedure to explore each relation \mathcal{X}_r . In the beginning of each relation's analysis more general information about the network will be provided. This is especially important for other SNA researchers in order to contextualise the findings and enable comparison to similar studies. The analysis begins with an exploration of the entire network. After that the network structure in the actors' localities is brought into focus. The analysis closes with considerations regarding interdepartmental relationships. Structural measures are only applied to networks that are reduced to surveyed actors. Measures including the entirety of actors would be significantly flawed by missing data on some network members.

Table 4.1: Identification key of partitioned actor classes.

| \mathcal{B}_k | Group | Key |
|--|------------------------|---|
| $\mathcal{B}_1 = \{a4, a13, a41\}$ | Management |  |
| $\mathcal{B}_2 = \{a5, a8, a14, a15, a16, a26, a30, a33, a34, a45, a48, a54\}$ | Engineering |  |
| $\mathcal{B}_3 = \{a24, a25, a31, a37, a43, a44, a50, a52\}$ | Production |  |
| $\mathcal{B}_4 = \{a1, a10, a18, a51\}$ | Technical |  |
| $\mathcal{B}_5 = \{a6, a7, a17, a19, a20, a35, a47\}$ | Engineering contractor |  |
| $\mathcal{B}_6 = \{a12, a28, a29, a38, a40, a49, a53, a55\}$ | Production contractor |  |
| $\mathcal{B}_7 = \{a2, a46, a56\}$ | Accounting |  |
| $\mathcal{B}_8 = \{a9, a21, a23\}$ | Human resources |  |
| $\mathcal{B}_9 = \{a3, a27\}$ | Safety |  |
| $\mathcal{B}_{10} = \{a22, a42\}$ | Stores |  |
| $\mathcal{B}_{11} = \{a11, a32, a36, a39, a55, a56\}$ | Other |  |

Initially, the network will be assessed visually in order to detect substructures that are locally less connected or more cohesive. Nodes of division or cleavage in the network can illustrate how the network might be decomposed into components. Thereafter, the network is scanned for cohesive subgroups and a number of centrality and prestige measures are employed to assess the properties of individual actors. Subsequently, a positional analysis challenges each actor's informal position in the operation, as opposed to his or her formal role. The analysis closes with a block model that assesses interdepartmental relationships and pays particular heed to tie strengths. An overview of the analysis procedure is shown in Table 4.2. Moreover, the following conventions apply to every network: arcs pointing towards a node signify that the node that is pointed to supplies information, advice or approval (indegree) to the node at the arcs origin. Every arc that originates at a node, represent a

receiving of resources (outdegree) at the node at the arcs origin. Hence, the arrows do *not* symbolise the “flow” of resources but the citations that are made by research participants. The conventions are vital in order to comply with the formal definitions of structural measures.

Table 4.2: Generic analysis procedure.

| <i>Step</i> | <i>Subject of analysis</i> | <i>Background section(s)</i> |
|-------------|-----------------------------------|------------------------------|
| a. | Essential network characteristics | 3.9.1 |
| b. | Visual Inspection | 3.9.2 |
| c. | Density and cohesive subgroups | 3.9.1 |
| d. | Degree distribution and prestige | 3.9.1 / 3.9.4 |
| e. | Closeness centrality | 3.9.2 |
| f. | Betweenness centrality | 3.9.2 |
| g. | Eigenvector centrality | 3.9.2 |
| h. | Proximity prestige | 3.9.4 |
| i. | Positional analysis | 3.9.5 |
| j. | Blockmodelling | 3.9.6 |

The SNA and a first interpretation of its findings are consciously combined in one section. Analysis results, and the interpretations thereof, are deeply intertwined and a split of the two may cause a considerable loss of context to the reader. It may be cumbersome to follow interpretations when these are not directly related to findings and accompanied by visual representations. To the benefit of the reader the analysis and interpretation of analysis findings are joined in one section. Thereinafter, section 4.5.7 consolidates various findings into results that point towards salient problem areas at the plant.

For convenience sake, each network that is investigated is identified by the sequence of a capital letter and the notation for the relation that has been defined on the actor set, where “ R ” or “ A ” identifies the case study and “ $\mathcal{X}_1, \mathcal{X}_2, \dots, \mathcal{X}_r$ ” identifies the respective relation that is referred to.

4.5.4 $A - \mathcal{X}_1$: Information Exchange

Network $A - \mathcal{X}_1$ consists of 63 nodes and 404 arcs, of which 15,6% represent weaker ties of monthly interaction. Out of 63 actors, 38 actors have been recalled freely. Hence, roughly 40% of the entirety of actors’ have been surveyed and about 60% have been recalled freely. The network attempts to grasp the flow of information among actors.

b. Visual Inspection

On first sight, it can be seen that the graph in Figure 4.2 suggests a core-periphery structure and that it contains numerous secluded nodes. The polarisation of a tightly meshed core and a secluded periphery structure is mainly attributable to the use of an expanding selection survey methodology. The majority of actors who are embedded in the denser network structure have been surveyed. Peripheral nodes were recalled by surveyed participants, but no data has been collected on them. That is, while the study boundary has been maintained, the study design allows for an investigation of the relational structure that frames the entity under investigation.

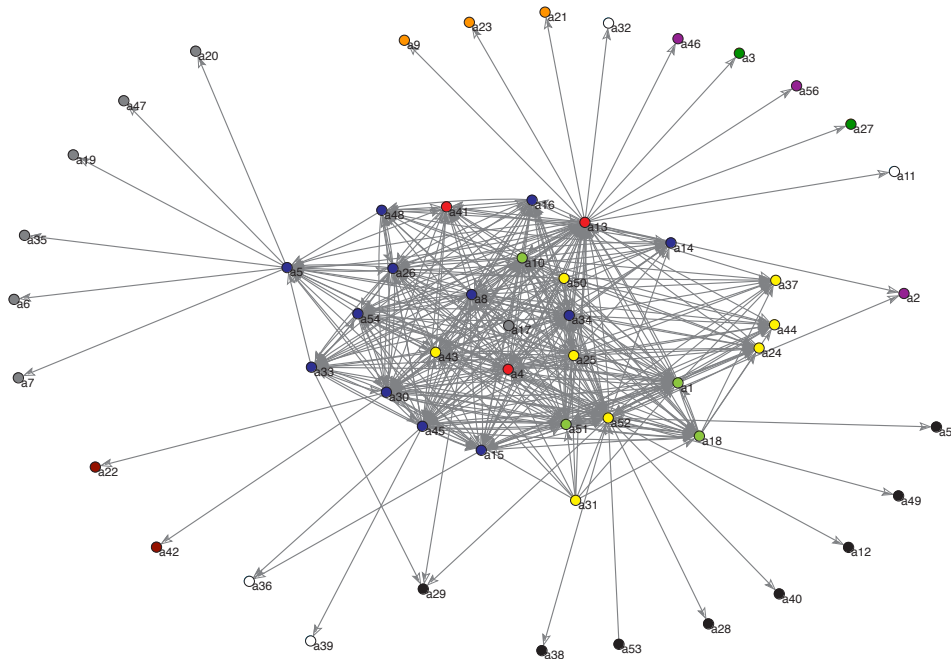


Figure 4.2: Network A – \mathcal{X}_1 .

In Figure 4.3, the network has been rearranged. Survey participants build the graph's core, actors from other resorts within the organisation build a first periphery and contractors are placed on a second periphery. The two nodes a37 and a44 (in the first periphery²) receive noticeably more citations than other actors in the same periphery. The nodes represent production shift leaders that are off duty. Although the nodes have been off-site for about two and five months respectively; information demands remain directed towards them. Clearly, it has to be compensated for the information supply that was provided by a37 and a44. The current network structure suggests that a compensation for information supply from these actors has not been

²Although a37 and a44 are part of the production class \mathcal{B}_3 , the nodes have been positioned in the first periphery to illustrate their absence.

accomplished yet. However, it must be kept in mind that results from SNA generally reflect on more stable patterns of interaction. The two nodes might not be as prominent in the “real” network as the analysis suggests. However, the reasonably long time periods of two and five months should weaken this effect. It may be questioned if substitutes can come up to their new roles and replace the supply of information that was provided by their predecessors. If this is not achieved yet, it should be discussed how adequate support can be anticipated. The migration of nodes a37 and a44 may also result in the loss an important links in the information exchange network, creating structural holes. The question is, if the gap in the information exchange network was closed, yet.

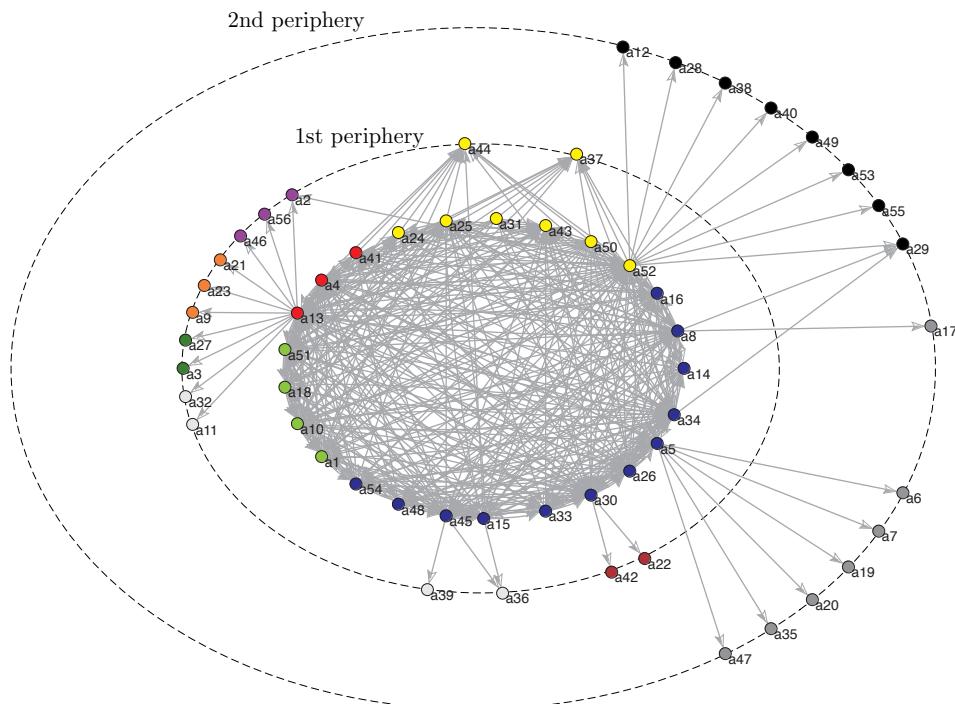


Figure 4.3: Network $A - \mathcal{X}_1$ core periphery structure.

Network $A - \mathcal{X}_1$ contains several cut-vertices and bridges, namely the nodes a5, a8, a13, a30, a45, a52. Bridges and cut-vertices are crucial to the flow of information because they can act as mediators but can just as well become bottlenecks in the network. The most critical cut vertices are nodes a5, a13 and a 52. Each of these nodes connects six or more single nodes. Node a13 receives information from a diversity of functional areas, making different pools of information accessible. The manager is an imperative liaison in information flows from other resorts. Exclusively the nodes a5 and a52 establish a connection to engineering and production contractors. Removing either node from the network disconnects the class \mathcal{B}_4 and \mathcal{B}_5 in

large parts. This gives rise to considerable concerns. Chapter 3 showed that PAMSE is very dependent on the participation of employees from every organisational level. Actors a5 and a52 are the exclusive corner posts that are able to take influence on as much as 15 individuals. In each case, information channels exclusively rest on a single actor. The circumstances of node a5 are especially intricate because 52 additional actors are connected to the six nodes actor a5 is adjacent to.

On the one hand the mutual information exchange between the operation and contractors is problematic because it has to be funnelled through single nodes. On the other hand, however, it might also be worth assessing how competencies are effectively sustained within the operation. Notwithstanding it might be considered that outsourcing core competencies at the very base of maintaining the plant also awards contractors with disproportionate bargaining power.

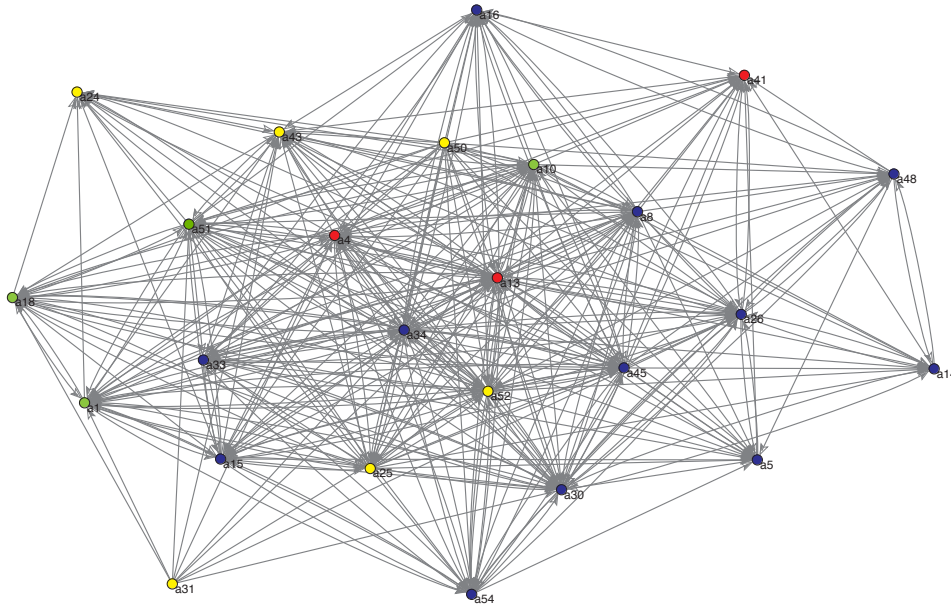
c. Density and Cohesive Subgroups

Structural measures are taken on the directed network $A - \mathcal{X}_1$ shown in Figure 4.4. The network consists of 25 actors that are connected by 404 arcs. The network achieves an average geodesic distance of 1.39 and an average degree of 18.88. Nevertheless, the network contains 48 unreachable pairs of actors. The network has an unexpectedly high density of 58%. A benchmark³ for information exchange suggests a density of 20% and cohesion of 2.0 for high performing information exchange networks. Although the benchmarks refer to network containing of about 50 actors (connectedness is dependent in a network is dependent on its size), the reference values are outscored by far. Apart from this, the network has an indegree centralisation of 0.307 and betweenness centralisation of 0.079. The closeness centralisation can not be determined because the network is not strongly connected. The essential network's properties are summarised in Table 4.3.

Table 4.3: Essential properties of $A - \mathcal{X}_1$.

| | | | |
|-----------|------------------------|--------------------|------------------------------|
| $g = 63$ | $L = 404$ | Free recalls = 38 | |
| $g = 25$ | $\Delta = 58\%$ | $C_D(d_I) = 0.307$ | $\bar{d}(n_i, n_j) = 1.39$ |
| $L = 348$ | $\bar{d}(n_i) = 18.88$ | $C_B = 0.0379$ | $\bar{d}_{I/O}(n_i) = 13.92$ |

³The benchmark is based on The Network Roundtable high performer benchmark database and was obtained from Activate Network Inc. (2012).

Figure 4.4: Network A – \mathcal{X}_1 core.

The network is exceptionally tightly meshed and information may flow freely among network members. The particularly high density may arise from extraordinary performance pressure on the operation that forces employees to close collaboration. Additionally, it was noted that employees and the operation itself are “young”, suggesting that junior employees might approach colleagues more often than it would be seen in a very experienced and established operation. Furthermore, the organisational culture seems to give advantage to a collaborative environment. The above factors may increase alliance among employees and contribute to the overall cohesion of the network.

Although the information exchange network is very dense, it may be compartmentalised into sections that are strongly connected in themselves but weaker connected to each other. Scanning the network for cohesive subgroups yields one⁴ large strong component of 23 actors that resembles 92% of network’s core structure. This is fairly unsurprising given the high density of the core structure. The cohesive subgroup excludes the vertices a31 and a50. A reasonable explanation would be that the actors a31 and a50 are not integrated into the strong component because they were just recently appointed to substitute the shift leaders a37 and a44, therefore being fairly new in their roles. It has to be mentioned that none of the two actors were included in the fixed list of the survey. The actors may also have been “forgotten”. However, the nodes do not receive a single citation; this strengthens the argument

⁴Considered that the minimum size of a subnetwork has been selected as three actors.

is their seclusion rather than an error in data collection. The analysis for cohesive subgroups does not point towards the existence of information “silos” at the plant.

d. Degree Distribution and Prestige

The connectedness of the network in its entirety has been looked at. In the following, the distribution of degree among actors will be closer investigated. On the one hand the distribution of degrees shows local concentration of ties around actors. On the other hand more secluded actors in the network can be identified. Because the network is directed, it will be distinguished between indegree and outdegree. The average in- and outdegree for the network is 13.92. Hence, on average each node receives and supplies information to 13.92 people. The box plot in 4.5 indicates that the the network shows a lesser dispersion of indegree than outdegrees. It is conspicuous that interactions of information reception vary over a greater range, while the majority of actors maintain a more homogenous indegree.

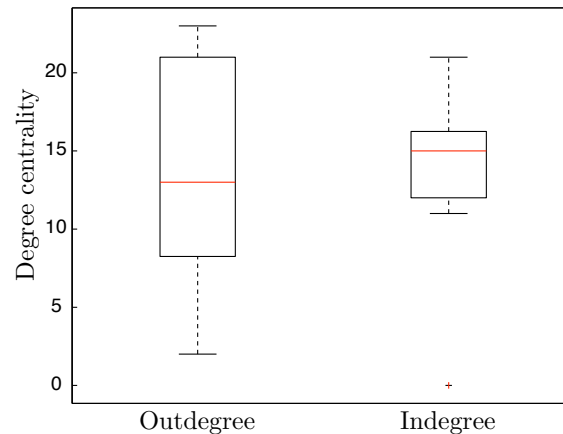


Figure 4.5: Network $A - \mathcal{X}_1$ degree boxplot.

For the analysis, the position of each actor is seen relative to other network members rather than in comparison to a benchmark. Figure 4.6 shows a scatterplot of the indegree and outdegree of every actor. The graph is divided into four quadrants. Quadrant I shows the *pivots* in the network, these are actors that function as brokers of information. Their indegree and outdegree are above the average $\mu = 13.92$. They distribute and receive information to and from more people than the average. Quadrant II shows actors which are *sources*, they have an above average indegree and below average outdegree. Actors that are sources provide more people with information than the average, but receive information from fewer people than the average. Quadrant III reveals less active actors in the network, their indegree and outdegree

is below average. The actors in quadrant III can be viewed as more *secluded* compared to the other actors. Quadrant IV shows high information *seekers*, while their indegree is below average, these actors receive information from more people than the average. The bottom shaded area indicates an indegree lower than the mean less double the standard deviation $\sigma = 5.041$. Actors in this area are outliers the PAM should pay particular attention to.

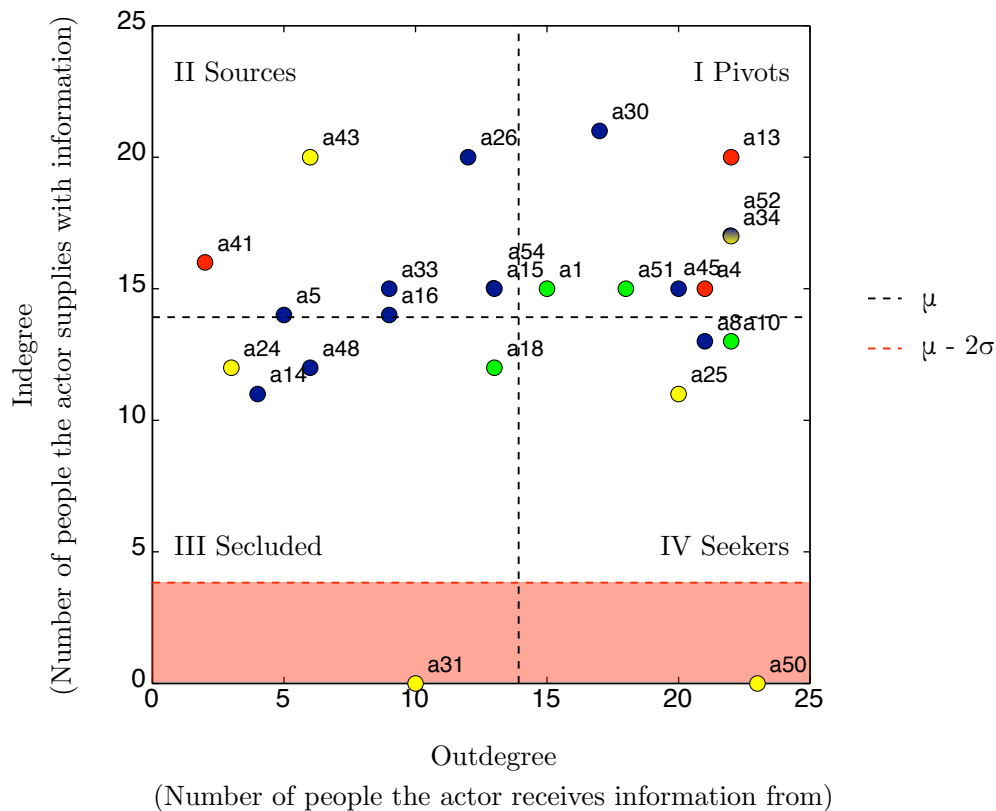


Figure 4.6: Network A – \mathcal{X}_1 degree scatter plot.

For network A – \mathcal{X}_1 , the analysis of cohesive subgroups suggested that node a31 and a50 lack integration into the network. Now it can be seen that the nodes are not mere outliers but do not receive a single citation; whereas other actors of similar occupation received at least 11 citations. It is important to point out that the actors were not registered in the survey's fixed list. Therefore, it may be reasonable to achieve less citations as other actors in the class \mathcal{B}_3 . A non citation however is most certainly accompanied by very little presence of a37 and a44 to other network members. Apart from this, it can be noted that node a50 is connected to more actors than a31. Actor a50 is more active in acquiring information. Assuming that the

actors are the substitutes for actors a37 and a44, both actors may be in the process of adopting the new roles. Again, it must not be forgotten that the SNA results are biased towards the long term and that the current situation may not be captured with the highest of accuracy.

The scatter plot shows a high number of information sources and pivots, while four actors can be considered high information seekers. The most prestigious actors are a13, a26, a30 and a43; they clearly occupy a central role in the trafficking of information. More troublesome nodes are a5, a14, a24, a41 and a48. In front of the background of the network's high connectedness, the connectedness of these nodes is untypical. There might be benefit in clarifying why the actors receive information from significantly less actors. Actor a5 has raised some attention earlier in the investigation. A possible explanation for the less active position in the network might be the actor's involvement with numerous contractors. The actor's capacities in exchanging information might already be strained by the sub-network to contractors; forcing the actor to withdraw from interactions in the network under investigation. Node a41 receives information from notably few colleagues. In a managing position the actor was expected to be supplied with information from a broader range of individuals. The information flow "up the hierarchy" appears to be problematic for this node, this may have negative effects to the actor's decision base. Node a14 and a48 perform in similar job positions. In comparison to the remainder of the network, they are least active. The actors low outdegree suggests questioning the definition of their responsibilities. Apart from nodes a52 and a43, the production class is characterised by an outdegree below average; the class maintains the fewest relations to other network members. The most important pivots are nodes a13, a30, a52 and a34.

e. Closeness Centrality

Due to the high density of the network, closeness centrality calculations are expected to deliver insignificant insight into the network; already the average geodesic distance indicated that all actors are very "close" to each other. For the computation of closeness centrality in a directed, not strongly connected network⁵, De Nooy *et al.* (2011) suggest to solely consider nodes that are reachable from the node under investigation and to weigh the summed distance by the percentage of nodes that are reachable. This advice has been employed. The results are illustrated in Figure 4.7.

⁵In a not strongly connected network, there are no paths between all actors. Hence, some actors are not reachable and distances can not be determined.

Nodes a31 and a50 do not have an indegree, they are not “reachable” for some nodes and attributed with an indegree closeness centrality of zero. The values for closeness centrality confirm the above expectations. The indegree closeness centrality is relatively constant across actors. However, for outdegree closeness centrality it can be found that some actors are somewhat more central than others. The actors that are closest to others in terms of receiving information from others are nodes a50, a10, a13, a34 and a52; it is the same actors that build the forefront of highest outdegrees. The measure reveals that the manager a41 is alarmingly distant from other network members. Already the degree distribution suggested that actor a41 is least involved in acquiring information. Closeness centrality fortifies this finding. The secluded position of actors a14 and a48 is also reflected by the analysis of closeness centrality.

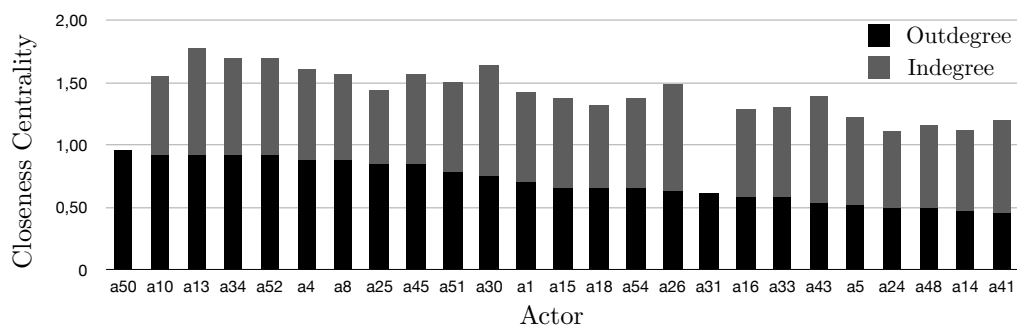


Figure 4.7: Network $A - \mathcal{X}_1$ closeness centrality C'_C .

f. Betweenness Centrality

The betweenness centralities for each actor are indicated in Figure 4.8a. The graph renders betweenness centrality as the circle size, delivering a first visual indication of the betweenness centralities among actors. Figure 4.8b and 4.8c unravel the distribution of betweenness centrality in greater detail. The bar graph identifies nodes a13, a26, a30 and a52 as major gatekeepers in the core-network. In many occasions, actors rely on the intermediary position of these gatekeepers in order to “reach” other actors that they are not directly connected to. The nodes’ betweenness centrality values exceed the networks average and the box plot highlights the nodes as statistical outliers. The most peripheral actors are a14, a24, a31, a41 and a50.

g. Eigenvector Centrality

Eigenvector centrality has been applied as an additional measure for centrality. Figure 4.10 shows actors that are important authorities (providing information) and

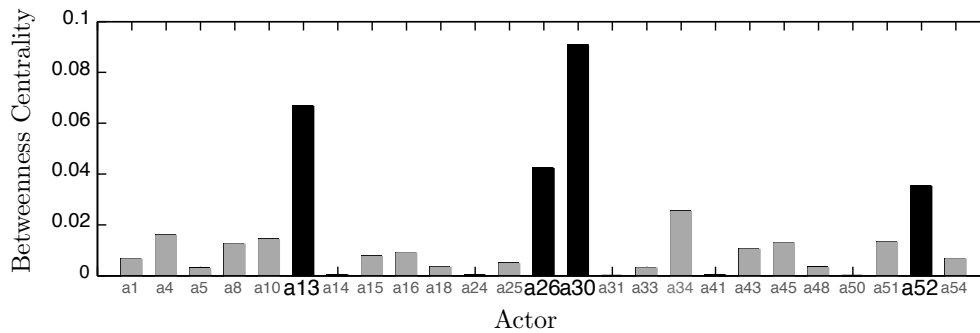
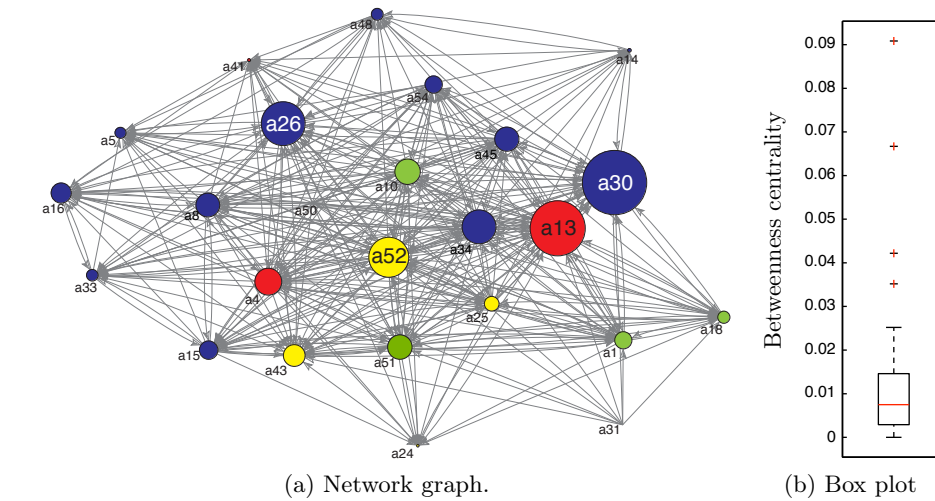


Figure 4.8: Network $A - \mathcal{X}_1$ betweenness centrality $C_B(n_i)$.

hubs (receiving information). Nodes a30 and a26 stand out as, the most balanced hubs and authorities, the two actors connect the most central actors and broker information between them. According to the boxplot in Figure 4.9, the actors a13, a26, a30, a43 and a52 are statistical outliers. Actor a13 is the most important hub in the network, the actor acquires information from highly central authorities. Actors a43 and a52 achieve the highest authority weights. They pass information to the actors of highest hub values.

h. Proximity Prestige

The proximity prestige is directly related to the input domain and the overall cohesion of the network is very high. Therefore, the measure delivers insignificant insight into the network structure.

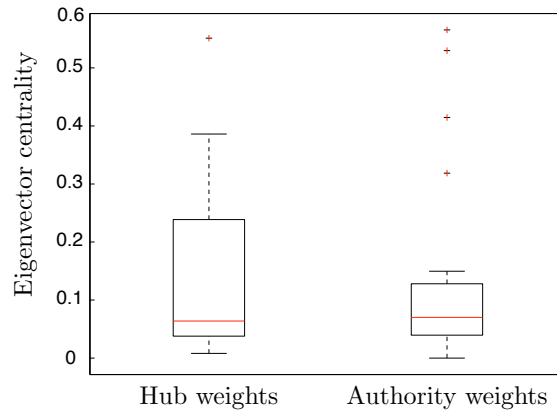


Figure 4.9: Network $A - \mathcal{X}_1$ eigenvector centrality e_i box plot.

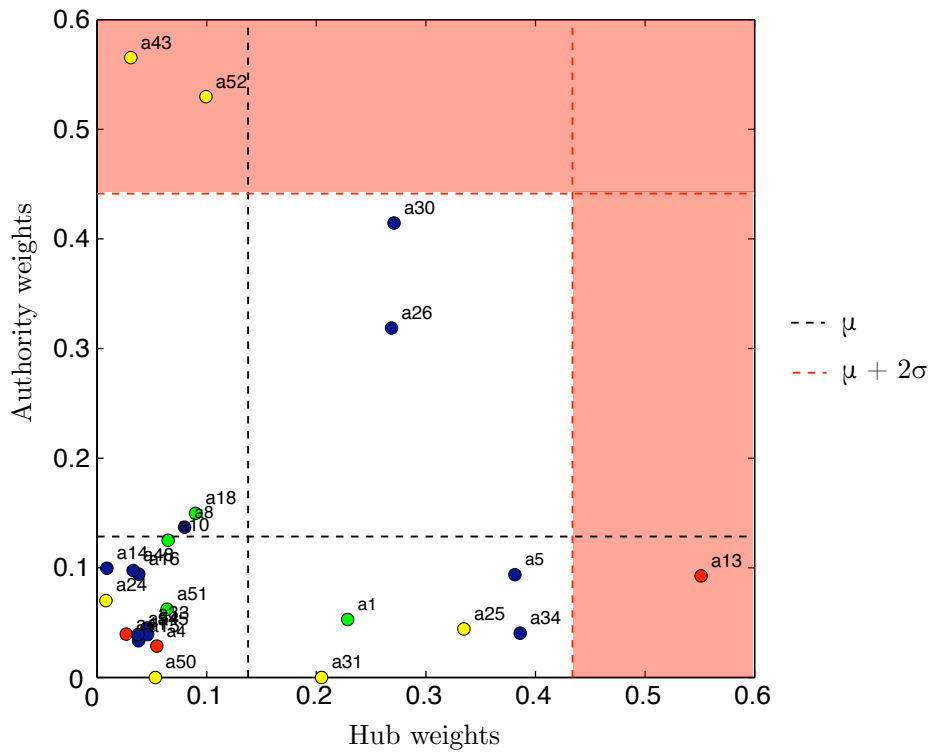


Figure 4.10: Network $A - \mathcal{X}_1$ eigenvector centrality e_i scatter plot.

i. Positional Analysis

The positional analysis and hierarchical clustering of dissimilarity values $d_{i,j}$ yields the dendrogram shown in Figure 4.11. In some cases, the positional analysis reflects the positions that are defined by the organisational hierarchy. Exemplary, two clusters are named. The cluster of node a5 and a16 represents engineering foremen

of process section two. The cluster containing nodes a1, a18 and a51 represents the concentrator's metallurgists. In both cases the positional analysis approximates the organisational structure. Nevertheless, the analysis also draws the attention to actor clusters that appear to conflict with the operations formal organisation, see cluster (1), (2) and (3).

Cluster (1) includes the principal technical manager a10 and the shift leader a25. Figure 4.6 showed a similar degree distribution of the two nodes. In conjunction with the network's high density, this may contribute to the similar position in the network. Nevertheless, it is debatable whether actor a25 has such very diverse information input from across the operation.

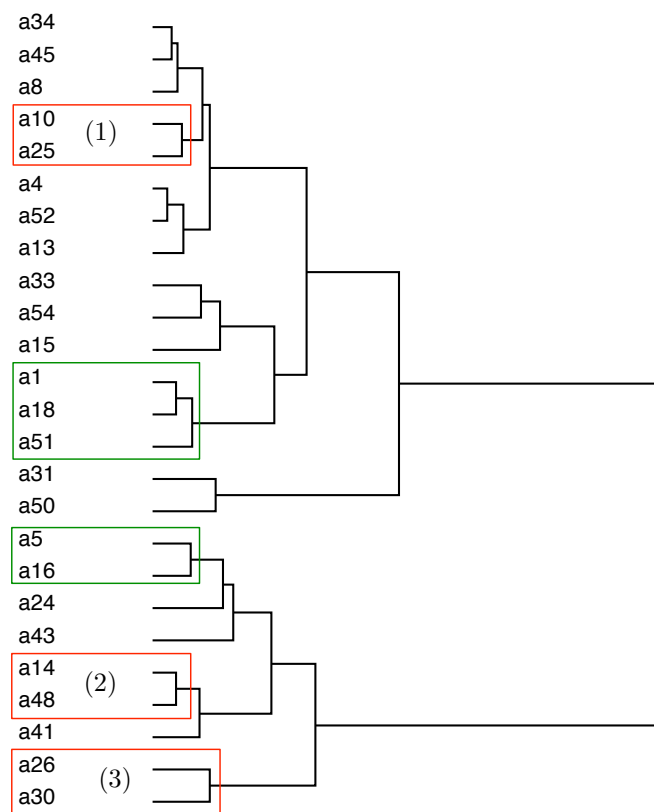


Figure 4.11: Network A – \mathcal{X}_1 dendrogram.

Cluster (2) contains two maintenance planners. It may be questioned why the planners are similarly embedded into the network, although they are responsible for maintenance planning of either one process section. A key influence might be the “single stream” nature of the production process. Ideally, maintenance activities may be scheduled in parallel between process sections in order to avoid downtime. Therefore, it may be necessary for planners to receive information from engineering

of both sections. The details of the present situation remain hidden to the analysis but it yields a pointer towards the organisation of the maintenance planning function. There might be room for improvement in stream lining information flows.

Cluster (3) consists of a section engineer and an engineering specialist. The positional analysis suggests that the actors share a large part of their neighbourhoods. In the light of information flows, the engineering specialist a26 resembles the position of the section engineer a30. Actor a26 emerges as an important source for information, as a hub and authority in the network, has some structural equivalence with a section engineer and also shows high values in betweenness and eigenvector centrality. There may be a connection between a26's informal role and the vacant position for a section engineer. The actor may be tied up in the role and responsibilities of an engineering specialist and those of an section engineer simultaneously. This raises the question if there is a double burden on actor a26. Further, it may be considered whether the actor is qualified to take ownership of the role of an section engineer. Nonetheless, the network structure surrounding a26 may be accompanied by an unclarity of responsibilities that boosts the density inside the engineering function.

j. Blockmodelling

The network $A - \mathcal{X}_1$ has been permuted using the classes \mathcal{B}_1 , \mathcal{B}_2 , \mathcal{B}_3 and \mathcal{B}_4 . Departments are thus treated as aggregated social units that define the position of actors they contain. In contrast to prior measures, the matrix permutation is used in order to gain understanding of information exchange habits between the different departments, rather than focussing on the individual. Figure 4.12 shows the block model. Information “flows” from rows (source) to columns (recipient). Squares in grayscale indicate the tie strengths between individuals and give a visual indication of the density within an between blocks (departments). The darker a cell, the stronger the relational tie between two individuals. The blocks *along* the diagonal refer to the tie texture within each department, whereas the blocks off the diagonal contain information about relationships among departments.

At first glance, it is noticable that position \mathcal{B}_2 features an especially high density within itself. The density in blocks, where information flows from engineering is noticeably more sparse. Incidentally, it can be seen that management only maintain strong ties to the actors a26 and a30 from the engineering class. This is especially alarming in the case of a41 who acts as the concentrators engineering manager. The actor's limited involvement with the engineering class might be a barrier to the deployment of strategic initiatives. Following, the densities for each block has been

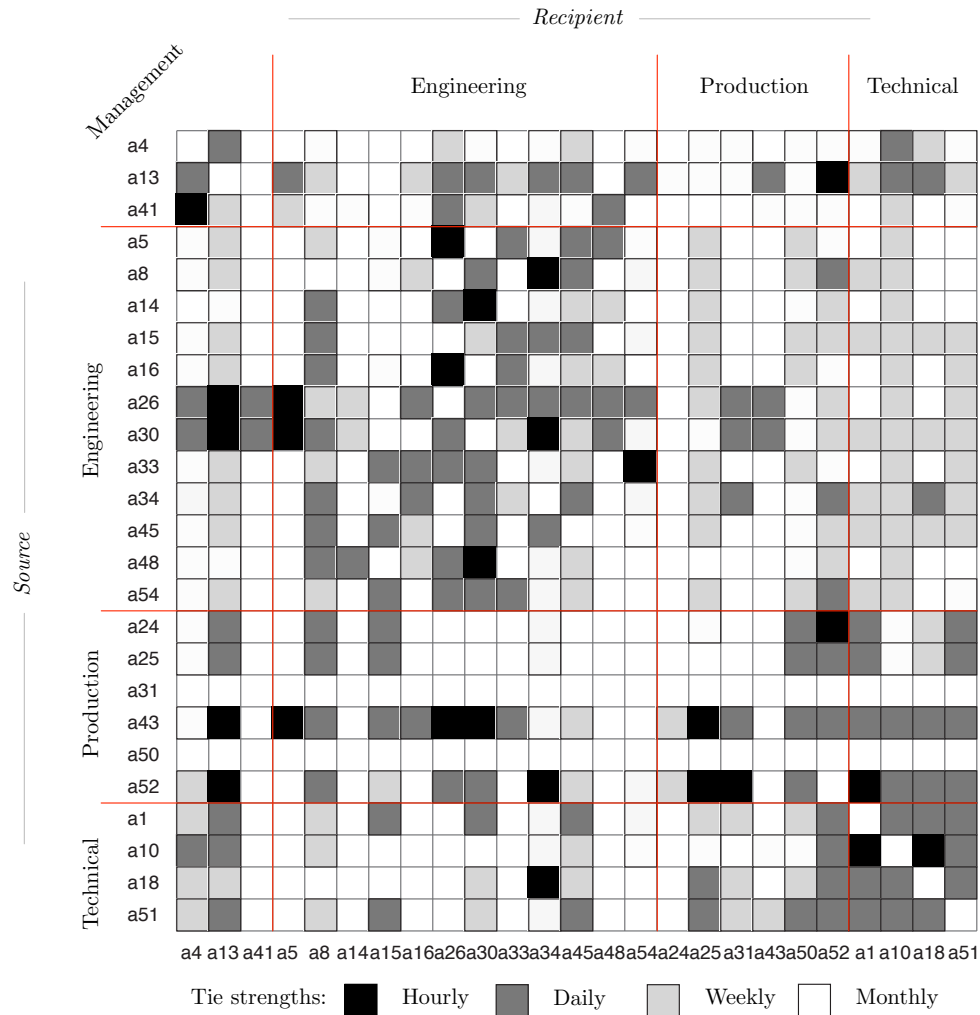


Figure 4.12: Network A – \mathcal{X}_1 block model.

calculated using binary and valued⁶ numeration. The density values for dichotomous numeration are shown in Table 4.4. The network’s remarkably high density also permeates the blockmodel. With a density of 46%, the production class shows least internal connectedness. The technical department forms a complete cluster with a density of 100%. The target collaboration for blocks along the diagonal should typically be 10 to 30%⁷. Because density is directly negatively related to network size and the benchmark applies to network sizes of about 50 actors, block densities for the network are expected to archive slightly higher scores. However, it can be seen that for the majority of blocks, the case study outperforms the benchmark by far.

⁶In order to get a more accurate representation of density, the valued numeration has been smoothed by transforming tie strengths with a value of 160 to a value of $v_{\max} = 20$. Hourly contact to every actor is not a reasonable baseline to employ because tie strengths of 160 occur rarely.

⁷The benchmark is based on The Network Roundtable high performer benchmark database and was obtained from Activate Network Inc. (2012).

The weakest connectivity among positions exists between engineering (receiving) and production, the block achieves a density of 30,56%. A second potential problem area is that the density of information supply by the technical department to engineering only accounts 37.50%. Even though both scores exceed the benchmark target, they clearly under perform in direct comparison to other departments.

Table 4.4: Network $A - \mathcal{X}_1$ block densities $\Delta_{\mathcal{B}_\alpha \rightarrow \mathcal{B}_\beta}$.

| | | <i>Recipient</i> | | | |
|---------------|-------------|------------------|-------------|------------|-----------|
| | | Management | Engineering | Production | Technical |
| <i>Source</i> | Management | 66.67% | 66.67% | 72.22% | 83.33% |
| | Engineering | 69.44% | 65.91% | 55.56% | 62.50% |
| | Production | 44.44% | 30.56% | 46.67% | 66.67% |
| | Technical | 66.67% | 37.50% | 70.83% | 100% |

For the density values shown in Table 4.5, line values have been considered. Mere binary numerated values give a crude picture of the dynamics between departments, whereas the valued density provides a more detailed picture of how information is trafficked. It appears that valued density measures do not change the relative internal connectivity of departments. The technical department sustains a density of 100% and production, again, shows the lowest score. It is surprising that although class \mathcal{B}_2 is double the size of class \mathcal{B}_3 , its density is higher.

Table 4.5: Network $A - \mathcal{X}_1$ valued block densities $\Delta_{\mathcal{B}_\alpha \rightarrow \mathcal{B}_\beta}^V$.

| | | <i>Recipient</i> | | | |
|---------------|-------------|------------------|-------------|------------|-----------|
| | | Management | Engineering | Production | Technical |
| <i>Source</i> | Management | 53.33% | 27.78% | 14.17% | 32.92% |
| | Engineering | 23.06% | 43.41% | 17.92% | 13.85% |
| | Production | 24.17% | 21.78% | 38.17% | 52.08% |
| | Technical | 40.00% | 17.19% | 35.63% | 100% |

The blocks of least density are found off the diagonal, between classes. The least active blocks include the mutual information exchange between the technical and engineering department. It seems like the two departments are most distant in terms of sharing information. Information flows rely on a density of only 13.85% and 17.19%, respectively. Despite this relationship, it can be seen that production receives little input from management and the engineering cluster. Only 17.92% of all possible “daily” ties exist with engineering and the figure drops to 14.17% in the case of the management class.

Block densities show to what degree the potential of ties within the network is realised. The density shows how cohesive two classes are. At present, the interaction proportions for each department are still unknown. It may be interesting to understand how a particular department apportions its communication between functional areas. Therefore, the proportion of supplied information $p_{\mathcal{B}_\alpha \rightarrow \mathcal{B}_\beta}$ has been determined for each class. Table 4.6 is read from row to column. Percentages in a row indicate the proportion of information exchange interaction that originates in the class in that row and is practiced with each recipient in columns. Exemplary it can now be seen that although class \mathcal{B}_4 realises a density of 100% in itself, only a portion of 35.76% of all the information exchange interactions that flows from the department, is supplied to itself.

Table 4.6: Network $A - \mathcal{X}_1$ relative information exchange interaction $p_{\mathcal{B}_\alpha \rightarrow \mathcal{B}_\beta}$.

| | | <i>Recipient</i> | | | |
|---------------|-------------|------------------|-------------|------------|-----------|
| | | Management | Engineering | Production | Technical |
| <i>Source</i> | Management | 16.24% | 50.76% | 12.94% | 20.05% |
| | Engineering | 9.75% | 67.29% | 15.15% | 7.81% |
| | Production | 9.73% | 36.69% | 25.62% | 27.96% |
| | Technical | 14.29% | 24.55% | 25.45% | 35.71% |

The values confirm that the production class receives the least input from management, here a low density is accompanied by a little share of the total information supply by management. As already suggested by the density, the proportions deliver confirming evidence that the engineering class trades the largest share of information with itself and comparatively little interaction addresses other classes. This may indicate a silo mentality within this functional area. It appears that the engineering

class and technical class are especially distant from each other. Engineering provides especially little information to technical, the interaction in block $\mathcal{B}_4 \rightarrow \mathcal{B}_2$ is minimal compared to blocks in the form of $\mathcal{B}_k \rightarrow \mathcal{B}_2$.

As a last step in investigating the block model, each block's share in the total information exchange interaction within the network has been calculated ($P_{\mathcal{B}_\alpha \rightarrow \mathcal{B}_\beta}$). Table 4.7 indicates that the network's least cross-functional supply of information involves the management class. These findings coincide with the insight from Table 4.6. Although the values of information exchange interaction with the management class generally appear low, it has to be considered that the class only exists of three actors. Therefore, the interaction are not necessarily problematic. When blocks involving class \mathcal{B}_1 are not considered, the Table delivers confirming evidence for a weak mutual relationship between classes \mathcal{B}_2 and \mathcal{B}_4 .

Table 4.7: Network $A - \mathcal{X}_1$ proportion of information exchange interaction $P_{\mathcal{B}_\alpha \rightarrow \mathcal{B}_\beta}$.

| | | <i>Recipient</i> | | | |
|---------------|-------------|------------------|-------------|------------|-----------|
| | | Management | Engineering | Production | Technical |
| <i>Source</i> | Management | 1.75% | 5.46% | 1.39% | 2.16% |
| | Engineering | 4.53% | 31.29% | 7.04% | 3.63% |
| | Production | 2.38% | 8.95% | 6.25% | 6.83% |
| | Technical | 2.62% | 4.50% | 4.67% | 6.55% |

4.5.5 $A - \mathcal{X}_4$: Advice in Decision Making

Network $A - \mathcal{X}_4$ contains information about the advice seeking in decision making. Analysing advice seeking in decision making requires a shift in the analysis paradigm. Advice is a discrete assistance to a certain problem and distinct from the flow of information among individuals. Nevertheless, an intermediate position enables an actor to pass on advice. The network shows the reliance of some actors on others in making decisions, possibly revealing where particular needs for advice are present, which actors are central in providing advice, who is pivotal in coordinating decisions or whether actors have particular intermediate positions. The analysis may discover decision making silos or show exceptional needs for advice across functions. Because the path length between two actors has no practical interpretation, the average geodesic distance of the network has not been determined. Apart from this closeness

centrality and proximity prestige are not applied. It is contended that a “close” location of an actor in a network insignificantly influences distinct advice seeking.

b. Visual Inspection

The entire network for relation \mathcal{X}_4 is shown Figure 4.13. It contains 33 actors, from which eight have been freely recalled. Actors are connected by a total of 246 directed ties. The graph denotes a periphery that mostly contains the freely recalled nodes. The periphery includes contractors in engineering and production (a17 and a29) and actors from other departments (a36, a39, a55 and a56). Generally, peripheral nodes are adjacent to single nodes that request their advice. However, node a36 receives two citations and it can also be seen that the actors a37 and a44 frequently receive citations from other actors. Contrary to the network $A - \mathcal{X}_1$, cut-vertices primarily request advice from single nodes and do not connect larger external cluster. Therefore, cut points in the network are not regarded critical. As noted for network $A - \mathcal{X}_1$, the popularity of nodes a37 and a44 may cause future problems if their roles in the network are not filled by substitutes.

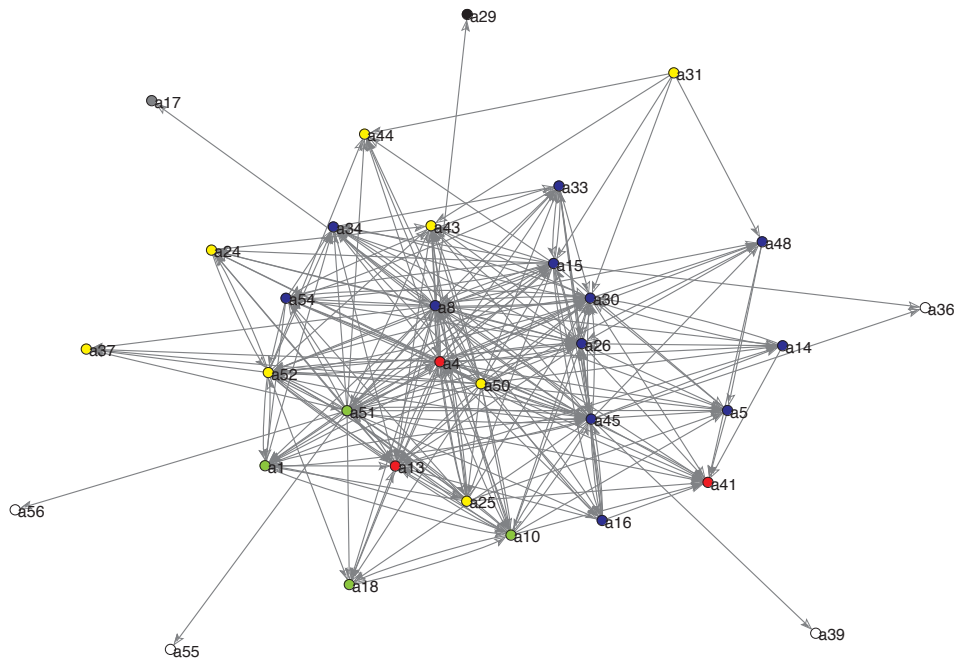


Figure 4.13: Network $A - \mathcal{X}_4$.

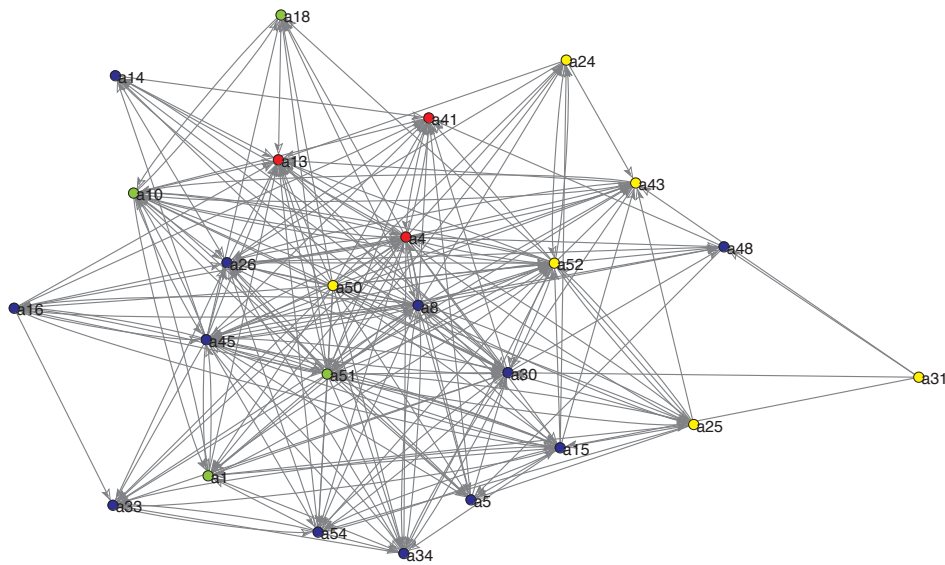
c. Density and Cohesive Subgroups

The core-network of advice in decision making is shown in Figure 4.21. It contains 25 actors that are tightly meshed by 227 directed ties. The network has a density of

37.8% and the average degree amounts 14.56. Apart from this, the network has an indegree centralisation of 0.344 and betweenness centralisation of 0.15. The network structure contains one strongly connected component and two isolated nodes: a31 and a50. The picture of a very reclusive position of the isolated nodes a31 and a50 maintains in network \mathcal{X}_4 . Not a single actor in the network depends on either of the actors a37 or a44 in making decisions. The network's properties are summarised in Table 4.8.

Table 4.8: Essential properties of $A - \mathcal{X}_4$.

| | | |
|-----------|------------------------|--|
| $g = 33$ | $L = 246$ | Free recalls = 8 |
| $g = 25$ | $\Delta = 37.8\%$ | $C_D(d_I) = 0.344$ $\bar{d}_{I/O}(n_i) = 9.08$ |
| $L = 227$ | $\bar{d}(n_i) = 14.56$ | $C_B = 0.15$ |

Figure 4.14: Network $A - \mathcal{X}_4$ core.

d. Degree Distribution and prestige

The network's degree distribution is displayed in Figure 4.15. The quadrants "Coordinators", "Advisers", "Passive" and "Clients" label the different characteristics of a node's degree. Nodes whose indegree and outdegree surpass the mean μ are called

coordinators. It is postulated that coordinators manage trade-offs between decisions. They coordinate complex decisions in the network by obtaining and providing advice from numerous actors. Quadrant II contains nodes with an indegree above average; the nodes are important *advisers* in the network as they support more people than they get supported by. The most *passive* actors in sharing advice are located in quadrant III. They are less active than the average actor in receiving or supplying advice in decision making. *Clients* are nodes that primarily receive advice from other network members but have an indegree below the mean.

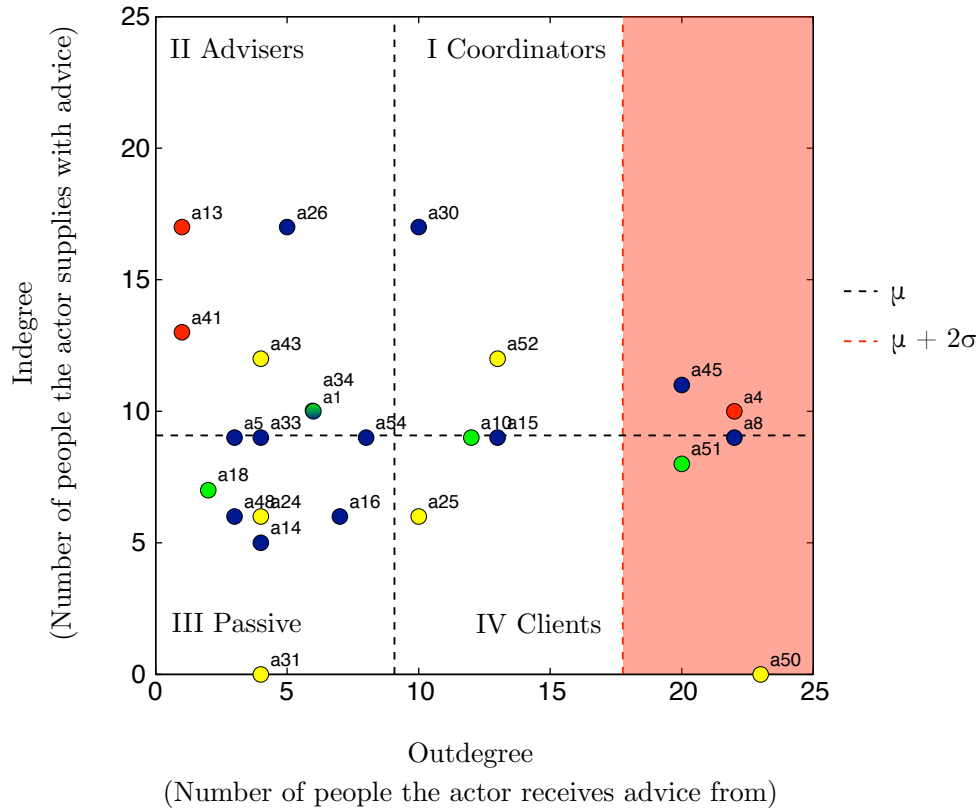


Figure 4.15: Network $A - \mathcal{X}_4$ degree scatter plot.

Nodes a4, a8, a45 and a51 are outstandingly active in receiving advice from other actors. Compared to most foremen, the nodes a8 and a45 heavily rely on input in making decisions. The node a4 is a senior manager, anticipating input from a greater pool of individuals may be considered a “good” quality for this position. In comparison to employees of similar occupation, node a51 stands out in receiving advice, the actor obtains significantly more advice than his peers. It is questionable whether the triple acts as coordinators or is, for some reason, particularly dependent in making decisions. Possibly this actor’s activity results from the vacant position of

the section engineer for process section two. Nodes a30 and a52 appear to maintain a balanced ratio of receiving and supplying advice, it seems like the nodes hold the assumption of coordinating decisions. Nodes a13, a26, a41 and a43 are the network's most prestigious advisers in decision making. They require less advice than the average but are important cornerstones in decision making. They are consulted the most when decisions are made. Quadrant three contains actors that are least active in obtaining or providing advice in decision making. It is proposed that the actors either do not require advice, base their decisions on less advice from peers or tend to shy away from making decisions. Before, network $A - \mathcal{X}_1$ pointed towards nodes a14 and a48 as being not very tightly embedded in the network. In the same way this can be found for relation \mathcal{X}_4 . Although the business processes within the plant are unknown; maintenance planners were expected to be in a more central position in the plants decision making processes. The evidence from the current network fortifies the possibilities of problems in the planning function and role definition.

f. Betweenness Centrality

Betweenness centrality has great value in the identification of actors that broker decision making. The degree distribution already suggested a selection of nodes that may take a coordinating role in the network. A centrality measure based on the concept of betweenness may identify the individuals that disproportionately broker or control the decisions amid actors. The results may be a valuable reference to the findings from the actors' degree distributions. Figures 4.16 display the betweenness centrality analysis results. The graphs highlights actor a4 as the most central node, followed by a30 in the second most central position. The actors a8, a10, a15, a26 a45 and a52 are located as "weaker" intermediates in the network.

g. Eigenvector Centrality

The eigenvector centrality measure is expected to reveal a small number of actors whose position in the network equips them with disproportional influence on key advice. Actors with high eigenvector centrality are adjacent to nodes that have a central role themselves. Authorities are nodes that are pointed towards by the arcs that originate in hubs. Actors a52 and a43 are important authorities, they provide advice to highly central hubs and might exert influence through these nodes. The nodes have a high indegree and are cited by many nodes with large outdegree. Node a25 points towards many central authorities, which makes the actor an important hub for advice.

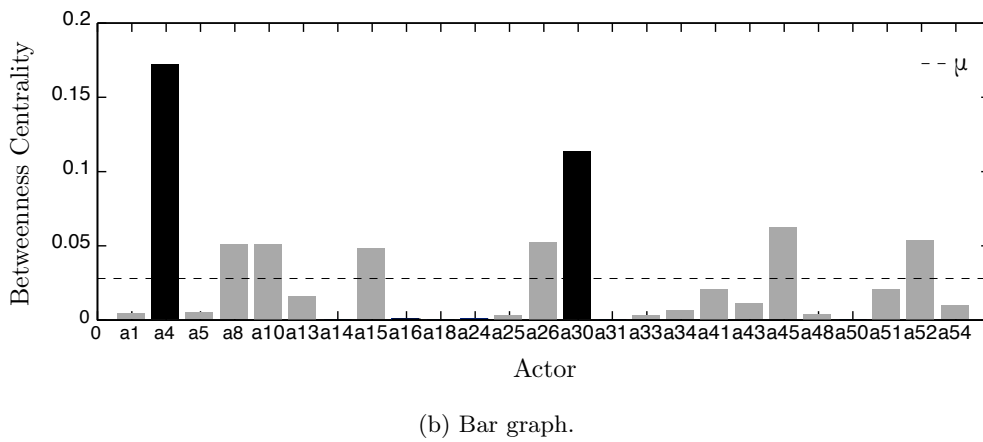
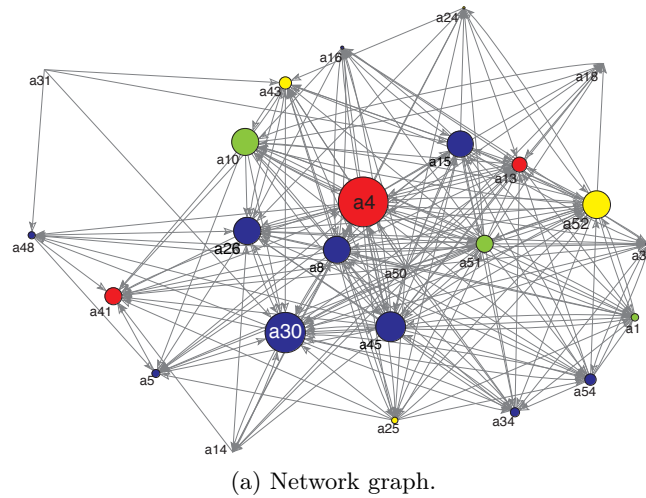


Figure 4.16: Network $A - \mathcal{X}_4$ betweenness centrality $C_B(n_i)$.

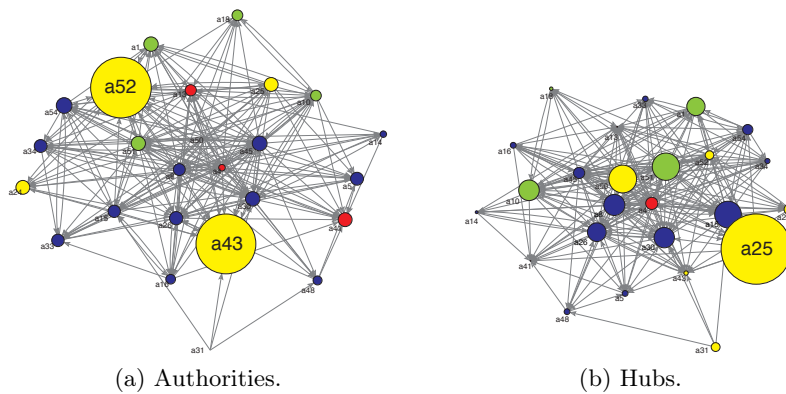


Figure 4.17: Network $A - \mathcal{X}_4$ eigenvector centrality e_i .

i. Positional Analysis

The positional analysis did not yield extensive insight to informal working structures. Nevertheless, additional evidence for important conjectures from previous analyses

have been discovered. The dendrogram in Figure 4.18 reaffirms the structural equivalence of actor a26 with managing positions in the network, this was already found for the relation of information exchange. The findings corroborate the informal position of actor a26 as a manager. Apart from this, the structural similarity of maintenance planners was found once more.

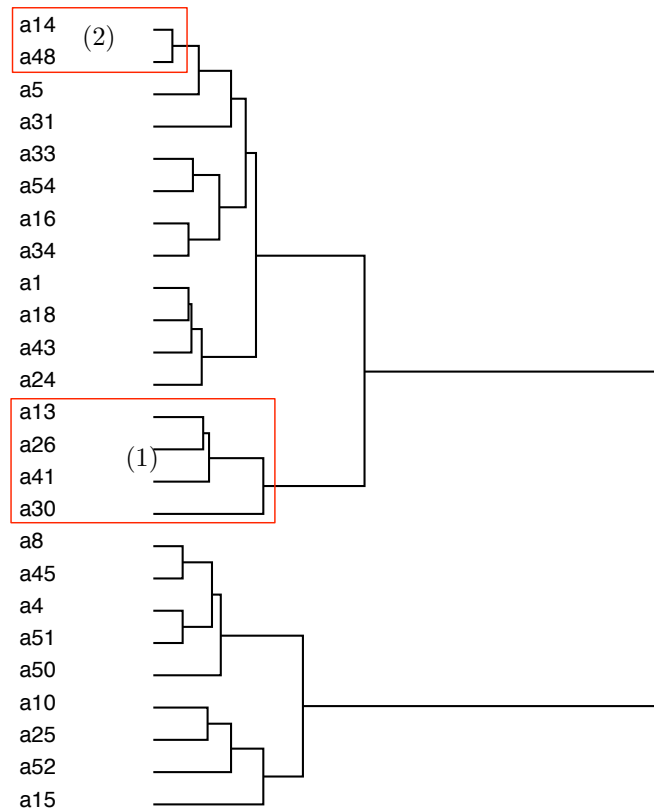


Figure 4.18: Network $A - \mathcal{X}_4$ dendrogram.

j. Blockmodelling

The adjacency matrix of network $A - \mathcal{X}_4$ has been permuted using the departmental classes \mathcal{B}_1 , \mathcal{B}_2 , \mathcal{B}_3 and \mathcal{B}_4 . The main tenet for the procedure is the location of inter departmental advice reliances. Overly dependent relationships across functions may stem from blurred responsibilities and inhibit decision processes. However, it is believed that there is a “healthy” degree of collaboration that can foster an effective cross-functional platform for making decisions. With this in mind, Figure 4.19 illustrates the block densities for advice in decision making within and across departments. The valued⁸ densities for each block have been calculated and are shown

⁸Block densities have been calculated using $v_{max} = 20$. Because merely two citations indicated a “hourly” tie strength a baseline of “daily” tie strengths appears to be more reasonable.

in Table 4.9. Table 4.10 shows the proportional advice input from the respective departments. Interpretations of these values are inherently different. Density values convey to which degree potential channels for advice are utilised, whereas the values in Table 4.10 display the proportion of advice activities that originate in one department and are dispersed between the remaining departments.

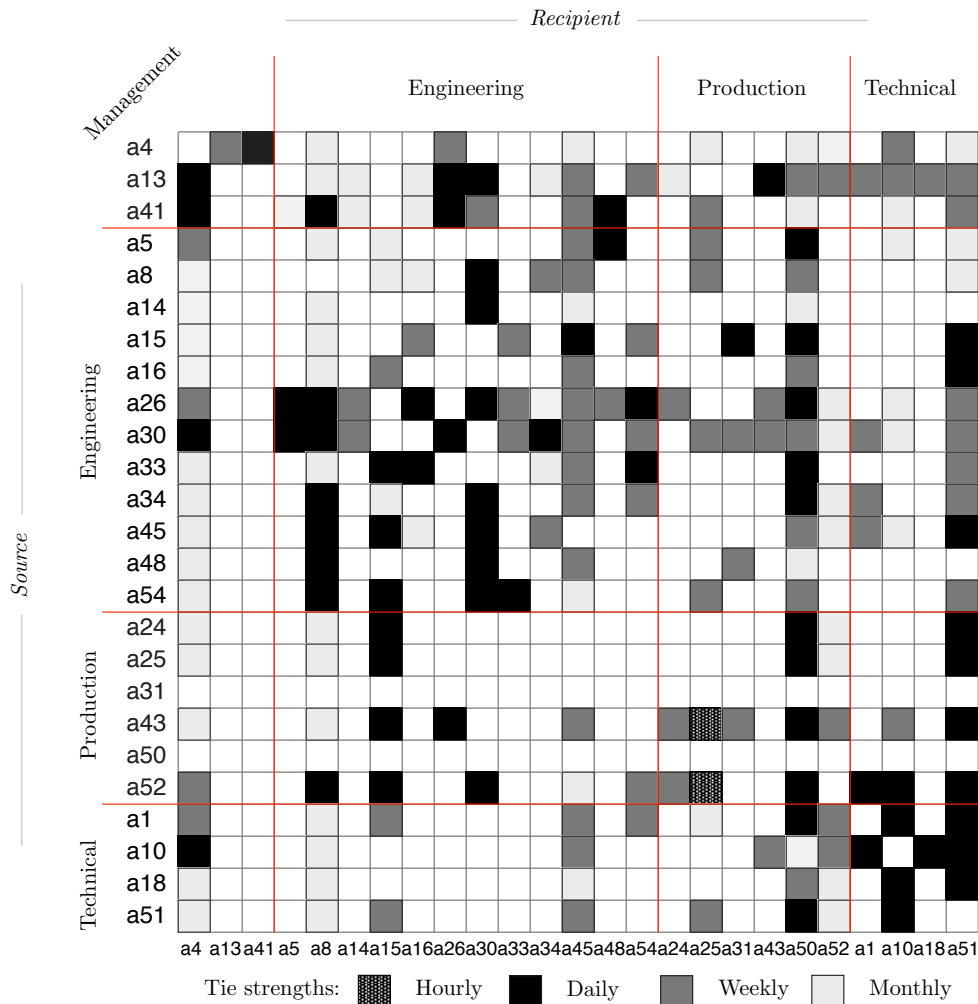


Figure 4.19: Network A – \mathcal{X}_4 block model.

The density within departments ranges from 23.00% to a maximum of 66.67%. The management and technical class exhibit the highest level of internal advising. They utilise more than half of the available ties to peers. Densities across functions are considerably lower. However, the block density $\Delta_{\mathcal{B}_4 \rightarrow \mathcal{B}_3}^V$ is an outlier with a value of 25.38%. The block model in Figure 4.19 reveals that actor a51 is the primary cause for the higher density. It can also be derived that this particular

Table 4.9: Network $A - \mathcal{X}_4$ valued block densities $\Delta_{\mathcal{B}_\alpha \rightarrow \mathcal{B}_\beta}^V$.

| | | <i>Recipient</i> | | | |
|---------------|-------------|------------------|-------------|------------|-----------|
| | | Management | Engineering | Production | Technical |
| <i>Source</i> | Management | 53.33% | 17.92% | 10.28% | 10.83% |
| | Engineering | 5.14% | 24.17% | 12.64% | 10.21% |
| | Production | 1.94% | 10.56% | 23.00% | 25.83% |
| | Technical | 10.83% | 3.02% | 13.33% | 66.67% |

actor accounts for nearly 80% and 65% of received advice from engineering and production, respectively. The lowest density is realised between the management and production class. The density $\Delta_{\mathcal{B}_1 \rightarrow \mathcal{B}_3}^V$ merely amounts 1.94%. It may be noted that solely manager a4 receives frequent advice from class \mathcal{B}_3 . The connection rests on a single tie of weekly interaction frequency to actor a52. The second lowest block density is $\Delta_{\mathcal{B}_2 \rightarrow \mathcal{B}_4}^V = 3.02\%$. Merely, actors a15 and a45 obtain significant advice from the technical department. Neglecting the actors a15, a45 and tie strengths with a value of one, advice from the technical department to engineering is absent. Apart from this the block model shows that only 5.14% of all possible advice ties exist in $\Delta_{\mathcal{B}_1 \rightarrow \mathcal{B}_2}^V$. Further, the network shows that only manager a4 obtains cross-functional advice in decision making.

The relationships between blocks are further investigated by not only assessing to which extend possible ties are used; but by determining which proportion of advice from a department is dispersed to others. In some cases, the analysis shifts the picture of advice seeking. Table 4.10 clarifies that in fact as much as 66.81% of the advice that is provided by engineering is retained internally. The density $\Delta_{\mathcal{B}_2 \rightarrow \mathcal{B}_1}^V = 17.92\%$ appears to indicate an intermediate interaction strength between engineering and management. However, when the interactions are viewed in relation to other departments, engineering receives more than half of the cross-functional advice that is provided from management. It can be seen that although the block $\mathcal{B}_2 \rightarrow \mathcal{B}_4$ shows the lowest realisation in ties with the technical department, the position receives more input than apparent by evaluating the density only.

The block density $\Delta_{\mathcal{B}_2 \rightarrow \mathcal{B}_3}^V = 10.56\%$ is the second weakest inter class connection to production. However, the few realised ties amount for the highest absolute share in advice provision by the production class. Mainly, this advice reaches actor a15.

Table 4.10: Network $A - \mathcal{X}_4$ relative advice interaction $p_{\mathcal{B}_\alpha \rightarrow \mathcal{B}_\beta}$.

| | | <i>Recipient</i> | | | |
|---------------|-------------|------------------|-------------|------------|-----------|
| | | Management | Engineering | Production | Technical |
| <i>Source</i> | Management | 25.00% | 50.39% | 14.45% | 10.16% |
| | Engineering | 3.87 % | 66.81% | 19.06% | 10.26% |
| | Production | 1.66 % | 36.10% | 32.78% | 29.45% |
| | Technical | 9.32 % | 22.94% | 22.94% | 57.35% |

The actor receives the majority of input from production among the engineering class. The weakest interaction with production is maintained by the management class. The block density $\Delta_{\mathcal{B}_1 \rightarrow \mathcal{B}_3}^V$ as well as the proportional interaction $p_{\mathcal{B}_1 \rightarrow \mathcal{B}_3}$ are minimal. An alarming density is $\Delta_{\mathcal{B}_1 \rightarrow \mathcal{B}_2}^V = 5.14\%$, especially if the proportional receiving of advice is consulted in parallel. The density $\Delta_{\mathcal{B}_1 \rightarrow \mathcal{B}_2}^V$ as well as the proportional advice interaction to management $p_{\mathcal{B}_1 \rightarrow \mathcal{B}_2}$ point towards a thin relational structure for the relation of decision advice. The decision base of management may become a problem if it is disconnected from the realities at the fundament of the operation. According to the analysis, the least advice from engineering reaches the management function and a large part of connections solely exists on a monthly basis. It has to be questioned if management decisions are based on incomplete information. Furthermore, Figure 4.19 reveals that actor a25 is the only network member that is in the need of hourly assistance regarding decision making. The most alarming relationship may be the advice provision by engineering to management.

Table 4.11: Network $A - \mathcal{X}_4$ proportion of decision advice interaction $P_{\mathcal{B}_\alpha \rightarrow \mathcal{B}_\beta}$.

| | | <i>Recipient</i> | | | |
|---------------|-------------|------------------|-------------|------------|-----------|
| | | Management | Engineering | Production | Technical |
| <i>Source</i> | Management | 3.35% | 6.75% | 1.94% | 1.36% |
| | Engineering | 1.94% | 33.39% | 9.52% | 5.13% |
| | Production | 0.37% | 7.95% | 7.22% | 6.49% |
| | Technical | 1.36% | 1.52% | 3.35% | 8.37% |

Table 4.11 presents the proportion of advice on the basis of the total interaction among actors ($P_{\mathcal{B}_\alpha \rightarrow \mathcal{B}_\beta}$). The most active connection exists between the production and engineering classes. The departments inter- and intra departmental relationships account for 58.08% of all advice trafficked. A substantive amount of advice is passed on within the technical class. The interactions with class \mathcal{B}_1 continue to appear considerably less active than other inter departmental relationships.

4.5.6 $A - \mathcal{X}_5$: Approval in Decision Making

Network $A - \mathcal{X}_5$ investigates relation five on case study A . The network represents the relational structure for decision approval. In contrast to relation \mathcal{X}_4 , the network pictures the plant like a control centre for decision making. Each citation equals an request that may result in approving or declining decisions. Approval does not get “passed on”; as decision rights are assumed to be defined on a particular individual. Therefore, betweenness and closeness interpretations of centrality do not find application in exploring relation \mathcal{X}_5 . Likewise to the analysis of other networks, structural measures are taken on the group of actors on which data was collected. Apart from this, the network has an indegree centralisation of 0.403 and betweenness centralisation of 0.156. The network’s properties are summarised in Table 4.12.

b. Visual Inspection

The decision approval network consists of 29 actors of which 4 have been freely recalled, the network is drawn in Figure 4.20. The directed graph is built of 123 directed lines. The freely recalled nodes a36 and a39 are approached by two engineering foremen who both specialise in the same field. Besides, actor a50 indicates that nodes a37 and a44 are approached for obtaining approval. It is questionable that an individual is bound to decision approval by peers of the same hierarchical level. Additionally, actors a37 and a44 are off duty. The graph illustrates a first problem area where decision authority may be unclear.

c. Density and Cohesive Subgroups

The directed graph of the network’s core shows 25 nodes that are connected by 118 directed lines. The networks density is 19.67% and it has an average degree of 9.12. The density closely approaches the benchmark level which has been set for a relation of information transfer. The network $A - \mathcal{X}_5$ utilises as many ties for approval obtainment as it is suggestive for a high performing information sharing network. Hence, the density level appears to be non-typical for a relation of decision approval. It is questionable whether decision making in this network is effective.

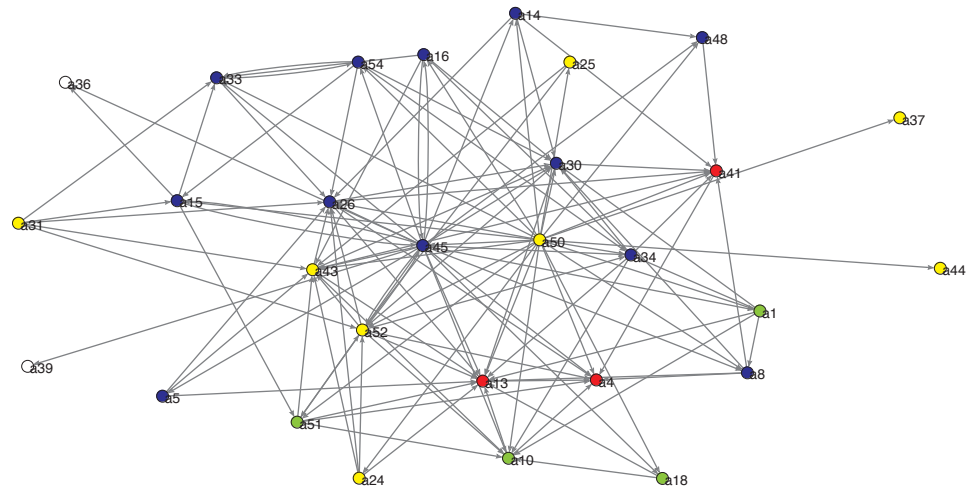


Figure 4.20: Network $A - \mathcal{X}_5$.

Table 4.12: Essential properties of $A - \mathcal{X}_5$.

| | | |
|-----------|-----------------------|--|
| $g = 29$ | $L = 123$ | Free recalls = 4 |
| $g = 25$ | $\Delta = 19.67\%$ | $C_D(d_I) = 0.403$ $\bar{d}_{I/O}(n_i) = 4.72$ |
| $L = 118$ | $\bar{d}(n_i) = 9.12$ | $C_B = 0.156$ |

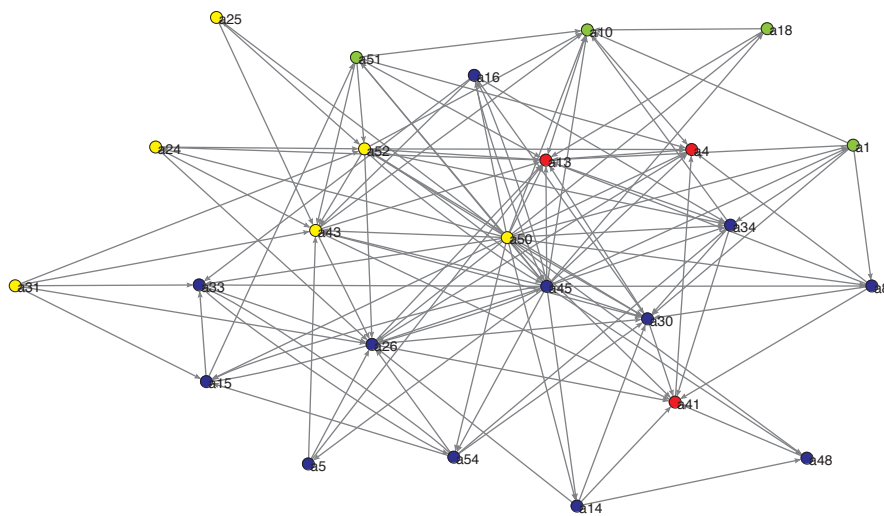


Figure 4.21: Network $A - \mathcal{X}_5$ core.

Cohesive subgroups may reveal conspicuous areas of concern. A pocket in the network that appears as a cohesive subgroup can be interpreted as a potential area of

redundancy or unclarity in decision rights. Within the group individuals are highly reliant on each others approval, potentially slowing decision approval processes. Initially, it was investigated whether the approval network contains bi-directional arcs. Bi-directional arcs imply that both actors require each others approval in making decisions. However, who obtains approval from whom may depend on the decision that is to be made. In network theory this means that cyclic sub networks exist, these may contradict with the organisational hierarchy. Four relationships of this type were identified, they involve the actor pairs: $a_{15} \leftrightarrow a_{45}$, $a_{16} \leftrightarrow a_{45}$, $a_{33} \leftrightarrow a_{54}$ and $a_{45} \leftrightarrow a_{41}$. The decision rights among these actor pairs may be evaluated in order to clarify the root cause of cyclic decision authority.

The analysis for cohesive subgroups yields a strong component that consists of seven actors. The component is shown in Figure 4.22a. The pocket of highly dense relational structure shows an increased dependency among the actors it contains. It may be noted that the strong component includes all four bi-directional arcs that are present in the network. Decisions that are to be made by any of the actors, in this highly dense part of the network are at risk. Conceivably, decision making processes are obstructed by mutual or widely spread approval processes. The relational structure within the cohesive subgroup may delay or deter decision making by restricting approval processes.

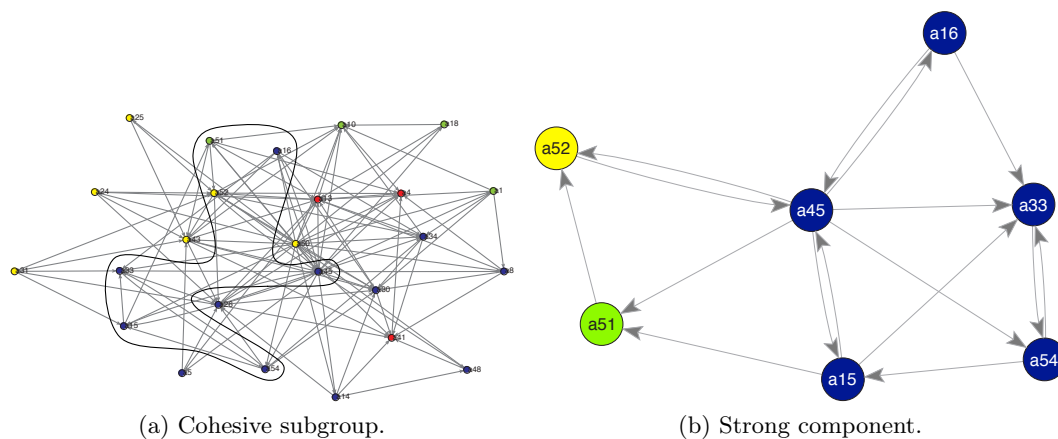


Figure 4.22: Network $A - \mathcal{X}_5$ strong component.

d. Degree Distribution and Prestige

The distribution of degree corresponds to the decision approvals in each actor's locality. The indegree or outdegree of an actor elucidates how active the actor is in

receiving approval for making decisions and approving the decisions of others. The degree distribution in Figure 4.23 shows clear alignment to the formal organisational structure. Actors that occupy a higher position in the organisational hierarchy have the highest indegree; their approval is required by many subordinates. Actor a13 is most prestigious, the actor carries the largest burden in the decision approval network. In total 14 individuals require the actor's approval in making decisions.

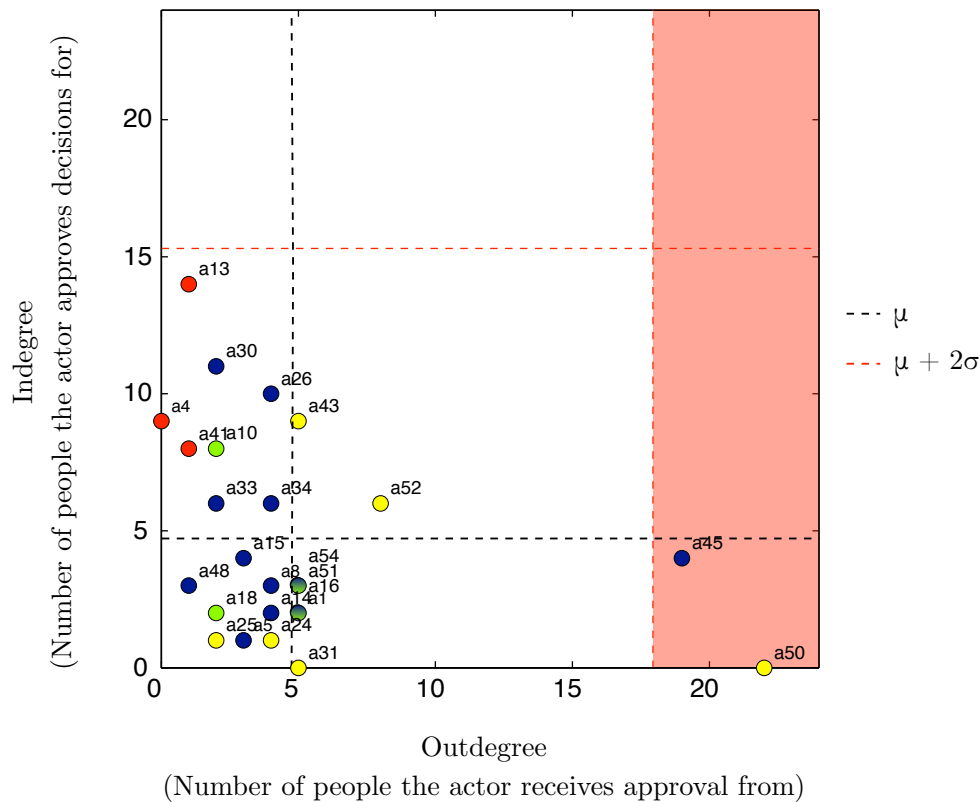


Figure 4.23: Network A – \mathcal{X}_5 degree distribution.

The position of actor a26 is unforeseen. The engineering specialist has the third largest indegree and is located in the midsts of the operations managers. Foremen a33 and a34 form the midfield between positions, their indegrees are slightly above average and their position approaches the managerial roles. Actor a45 and a50 are striking outliers, their respective outdegree exceeds the double standard deviation from the mean. The actors' high outdegree may point towards unclarity in decision rights or highly ineffective allocation of decision rights. Actor a4 is the highest level manager among survey participants, the individuals that have the authority to approve a4's decisions lie beyond the boundary of this study, therefore the actor's outdegree is zero. Surprisingly, it can be seen that apart from actor a31 and a50

every actor has an indegree greater than zero. That is, 92% of the surveyed actors give decision approval to at least one other actor.

Four main suggestions arise out of an analysis of degree. Firstly, there might be some considerable unclarity in decision making or ineffective allocation of decision rights for nodes a45 and a50. Secondly, it emerges that managers obtain highly active roles in the network decisions may frequently be elevated and responsibilities not taken where they are defined. Relation \mathcal{X}_5 once more confirms a dual role of actor a26.

g. Eigenvector Centrality

The results from an analysis of eigenvector centrality are virtually identical to the results from network $A - \mathcal{X}_4$. Actors a43 and a52 are clearly achieve the highest authority weights in the network and actor a25 is identified as the network single most central hub.

i. Positional Analysis

A positional analysis illustrates the polarisation of managing and subordinate actors likewise to Figure 4.23. Apart from that, no expedient results could be derived from the analysis.

j. Blockmodelling

The permutation of a sociomatrix is used to shed light on inter positional relationships. For relation $A - \mathcal{X}_5$ a block model is used in order to understand how approval in decision making interconnects the plants functional areas. The associated block-model is shown in Figure 4.24.

The model grasps the hierarchical structure in the plant. Evidently, the management position does not receive approval in decision making. This is because the highest authority is inherent in this class. As class \mathcal{B}_2 has the highest decision authority; the network reaching out to the management class is generally meshed tighter. This impression corresponds to the indications provided by the distribution of degrees. Figure 4.23 as well as the densities in Table 4.13 may point towards a situation where decisions tend to be elevated to the management class unreasonably often. The findings suggest that decision responsibilities are not taken by some actors and the decisions are pushed off to a manager.

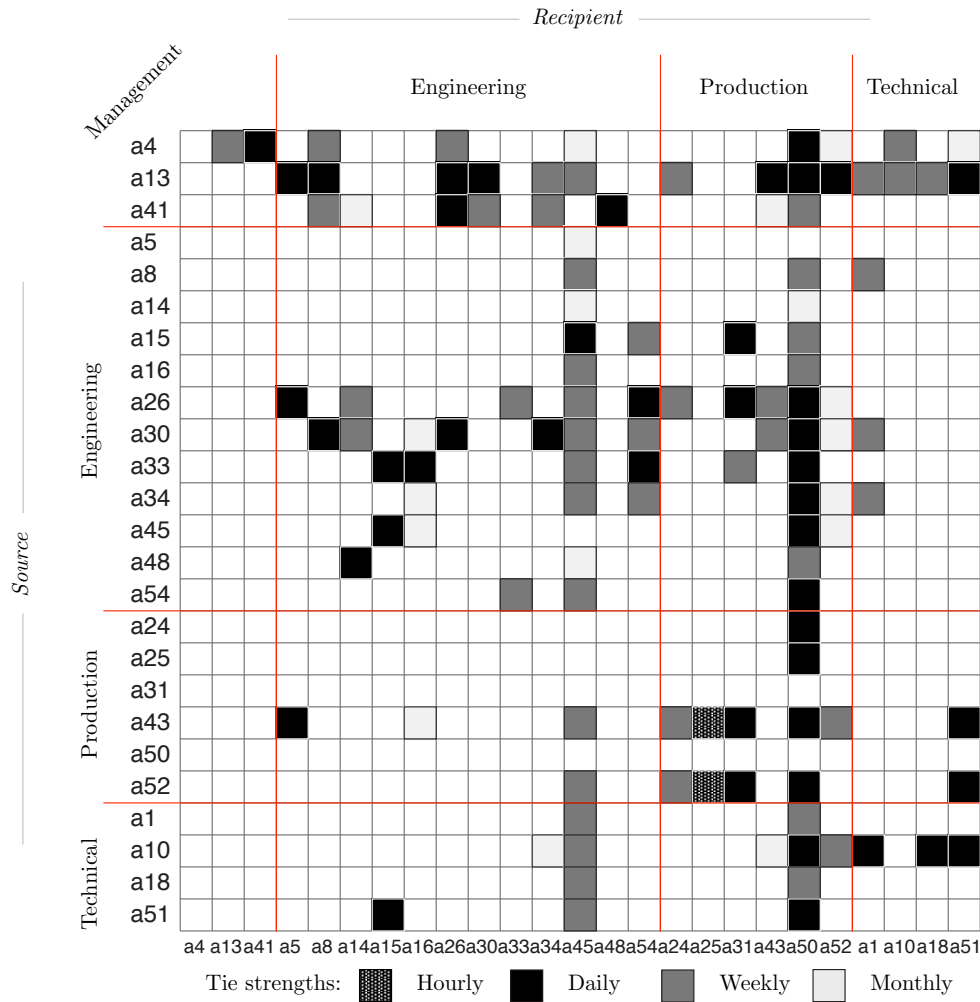


Figure 4.24: Network A – \mathcal{X}_5 block model.

With the exception of actor a45, the decision processes between class \mathcal{B}_2 and \mathcal{B}_4 are largely uncoupled from each other. This is illustrated by the block model and the valued densities presented in Table 4.13. The actor a45 appears as intermediary between the engineering and technical class. There is an unbalanced dependency for approval between engineering and production. While the production class relies on a considerable amount of approval for its decisions from engineering ($\Delta_{\mathcal{B}_3 \rightarrow \mathcal{B}_2}^V = 13.58\%$, $p_{\mathcal{B}_2 \rightarrow \mathcal{B}_3} = 40.12\%$), engineering utilises only 2.01% of possible ties and draws on 12.03% of the approval that leaves production, see Table 4.14. The highest density exists within the production class. This most cohesive block is closely followed by the relationship of production and management and the interdepartmental cohesion of the technical class. According to the block model, the high density of blocks involving the production class is mainly caused by the outdegree of actor a50.

Table 4.13: Network $A - \mathcal{X}_5$ valued block densities $\Delta_{\mathcal{B}_\alpha \rightarrow \mathcal{B}_\beta}^V$.

| | | <i>Recipient</i> | | | |
|---------------|-------------|------------------|-------------|------------|-----------|
| | | Management | Engineering | Production | Technical |
| <i>Source</i> | Management | 20.00% | 20.83% | 25.00% | 15.42% |
| | Engineering | 0.00% | 10.68% | 13.68% | 1.25% |
| | Production | 0.00% | 2.01% | 28.67% | 8.33% |
| | Technical | 0.00% | 3.85% | 11.04% | 25.00% |

The measure of density gives an indication of the realised potential of approval processes between two classes. Table 4.14 delivers an understanding of the portion of approvals traded to the respective departments. In order to get a quick overview of the overall proportion of approval traded by each block, Table 4.15 is presented. Here, percentages indicate the proportion of approval interaction relative to the total interactions that are present in the network. Correspondingly, the majority of approvals happen within the engineering class. The second most approvals reach production and are issued by engineering. The two blocks account for over 40% of the entirety of approval activities.

Table 4.14: Network $A - \mathcal{X}_5$ relative approval interaction $p_{\mathcal{B}_\alpha \rightarrow \mathcal{B}_\beta}$.

| | | <i>Recipient</i> | | | |
|---------------|-------------|------------------|-------------|------------|-----------|
| | | Management | Engineering | Production | Technical |
| <i>Source</i> | Management | 7.97% | 49.83% | 29.90% | 12.29% |
| | Engineering | 0.00% | 57.43% | 40.12% | 2.44% |
| | Production | 0.00% | 12.03% | 71.37% | 16.60% |
| | Technical | 0.00% | 24.67% | 35.33% | 40.00% |

Table 4.15: Network $A - \mathcal{X}_5$ proportion of decision approval interaction $P_{\mathcal{B}_\alpha \rightarrow \mathcal{B}_\beta}$.

| | | <i>Recipient</i> | | | |
|---------------|-------------|------------------|-------------|------------|-----------|
| | | Management | Engineering | Production | Technical |
| <i>Source</i> | Management | 2.03% | 12.68% | 7.61% | 3.13% |
| | Engineering | 0.00% | 23.84% | 16.65% | 1.01% |
| | Production | 0.00% | 2.45% | 14.54% | 3.38% |
| | Technical | 0.00% | 3.13% | 4.48% | 5.07% |

4.5.7 Results

The investigation of informal networks in Case Study A bears a number of findings. In total the SNA yields 24 findings of which some call the attention to potential problem areas. In some cases, different conjectures mutually reinforce each other and form a coherent picture of a problem. In these instances, it is desired to consolidate findings into plausible pointers on how the networks' fabrics can support or impair the execution of strategic initiatives; multiple results are consolidated to the primary constraints in PAMSE.

The presentation of results favours findings that are expected to have the greatest significance in influencing future PAMSE efforts. Therefore, the interplay of most noteworthy results is elaborately presented in this section and the abridged presentation of every finding is deferred into Appendix F.

Overloaded Key Actors

(Consolidation of results no. 2, 6, 7 and 8. See Appendix F)

A great deal of the success in strategy execution springs from particular individuals who engage in a strong leadership role; people who are capable to drive strategic initiatives with great momentum and close knit collaboration between strategically important groups. In Case Study A , three actors prevail in such valuable position.

The informal working dynamics equip actors a13, a26 and a30 with disproportionate power. Actor a13 is the most central hub for information, an important pivot for information exchange and outstandingly close to the network members of every organisational department. Actor a30 takes a similar pivotal role in trading

information but achieves an even higher betweenness centrality in the information exchange as well as in the decision advice network. Both actors provide substantial advice in decision making to other network members. Although both actors are the most prestigious actors across every relation, actor a13 is slightly more popular in providing decision approval to others. The actors a13 and a30 occupy the most central positions in the informal organisation, they take key roles that are empowered to disproportionately influence the entire network. Similar properties are found for actor a26, however, this actor's position in the network does not seem as intermediate.

According to Figure 4.1 actor a13 is the plant manager, a30 is a section engineer and a26 is an engineering specialist. The informal organisation's key actors occupy different formal positions in the organisational hierarchy. However, the positional analysis delivers significant evidence that actor a26, in fact, adopts a more managerial role in the informal organisation. Most presumptively this behaviour is driven by the additional workload that flows from the vacant position of a second section engineer. Seemingly, actors a26 and a30 compensate the vacant position of a second section engineer in tandem. The question that overarches this finding is, whether the potential from the informal position of a26 is or can be utilised to the plants benefit, or whether the actors informal role obstructs working dynamics. Three key questions can be derived. Is actor a26 overloaded? Is actor a26 effective in *either* role? Does actor a26 have the qualities to fulfil a managing role adequately?

Actor a26 occupies a double role at the plant. The actor is a engineering specialist while simultaneously taking a coordinating role in the informal network. This role resembles the formal position of a section engineer. The double role of actor a26 may be followed by a double burden that overloads the actor and impedes his or her effectiveness in either function. Apart from this, it must be kept in mind that the informal position of actor a26 does not imply any formal authority. Responsibilities get funnelled through a26 but eventually require the involvement of a30 or even a13. That is, while the network suggests a coordinating role of a26, decisions and major concerns may eventually be offloaded to either actor a13 or a30, see block models. This creates additional cohesion but is least effective. Because a26 is caught up in two roles, the actor may also be surrounded by an unclarity in responsibilities and become a salient constraint in informal working dynamics, especially when additional strategic initiatives add up to the workload of day to day tasks. Earlier, it was postulated that key positions in PAMSE have to be harnessed with two qualities: motivation and capability. The network reflects the prominence and activity of actor a26 in informal networks. Despite motivation and connectivity of an actor, he or she also has to be trained adequately. A lack of understanding and appreciation

of the strategic processes and the anticipated benefits may create resistance and turn a key actor's non education into a major obstacle to strategy execution. It has to be questioned whether a26 can support strategic aspirations with the advocacy they desire. Nonetheless, it has to be realised that despite possible problems, there is great potential innate in the informal position of a26. For the case that the actor contains the qualification to facilitate a strategically important role, his or her informal position may be utilised to much greater benefit of the operation, possibly resulting in considerable relieve of actor a30. In any case, management should provide a26 with a clear definition of his role and responsibilities and award the actor with the authority that is required to fulfil tasks effectively. Actor a26 may potentially constitute an important position in the informal network that can aid actors a13 and a30 and compensate for the vacant position of a section engineer. It has to be considered whether a26 is already overloaded and ineffective due to his double role at the plant. It has also to be considered whether the actor has the qualities that are necessitated by a key position to facilitate strategic initiatives. A clear role definition has to be developed.

Concerns regarding actor a13 intensify in the network $A - \mathcal{X}_3$. The analysis shows that decision making networks achieve a higher centralisation. The highest centralisation is found in the decision approval network. Here, centrality clearly culminates in the position of actor a13. Actor a13 stands out as the most prestigious actor in providing approval for decisions. Figure 4.23 illustrates that as many as 14 different network members are provided with approval for their decisions. The plant manager is the plant's primary focal point in obtaining approval for decisions. It appears that numerous decisions get elevated to a13, although the responsibility for some decisions may remain with the plant manager's subordinates. It is questionable whether decision rights are ineffectively allocated or if some actors shy away from taking responsibility for the decisions rights allocated on them. In either case, the "current" situation is prone to causing a cumbersome role of actor a13. Additionally decision making is slowed down and the strategically important connectivity of a13 is given away.

The above points towards the single most important trait of successful strategy execution as brought forward by Neilson *et al.* (2008): "Everyone has a good idea for the decisions and actions he or she is responsible". The role definition of a26 may be diluted by the actors involvement in a dual role. Actor a13 may be overloaded by elevated decisions that are not carried out by subordinates. In either case an important factor for success in strategy execution is at stage. Moreover, actor a30 may be overburdened because the plant is missing a second section engineer.

The introduction of strategic initiatives and improvement project necessitates the coordination of additional information, advice and approval. Naturally, the most accessible, highly skilled and most valued peers are approached preferably, boosting the thrust upon them. In important initiatives the network is predetermined/doomed to hinge on the key role of a13, a26 and a30. The actor triple may eventually limit the flow of resources because the actors operate at the limit of their capacities. It is doubtful that the actors can effectively promote strategic PAM initiatives in their current position because they are likely to be overloaded. This implies a choke for the effectiveness of the entire network. However, if a more balanced connectivity can be achieved and the networks' centralisation can be lowered, actors a13, a26 and a30 are the actors that are in the most advantageous position to compellingly support future PAMSE initiatives.

Albeit, an actors central quality is twofold. On the one hand a central role leverages an actor's ability to effectively influence member of informal networks. On the other hand the corner posts to the dispersion of resources can unintentionally become bottlenecks in the organisation's informal networks. The highly knowledgeable actors attract many peers that seek their support. Eventually, the highly capable actors get overburdened and induce substantial inefficiencies to working dynamics.

Collaborative Breakdowns

(Consolidation of results no. 4, 5 and 19. See Appendix F)

Pertinent information regarding PAM ambitions has to be effectively communicated in order overcome organisational barriers and to conjoin the activities of departments towards common targets. The SNA pinpoints critical junctures in informal networks where information exchange is substandard and interactions should ideally be advanced.

Visually assessing the network of relation \mathcal{X}_1 in Figure 4.3 highlights several cut-vertices. The cut-vertex a5 is of particular importance because the actor is the sole link to as many as 58 individuals that are contracted for engineering services. The tasks facilitated by contractors lie at the heart of the plant physical asset care, this accentuates the role that is facilitated by actor a5. The actor is the only channel for information that is to reach the individuals that maintain physical assets and facilitate an operational state of process machinery and infrastructure. These individuals are the fundament of the plant. However, the link to the entirety of contractors rests upon a5. This actor is an indispensable gatekeeper and can just as

well become a perilous bottleneck for vertical communication in PAMSE that cuts off the communication to engineering supervisors and artisans. An actor's capacities in exchanging information are limited. It is debatable how many information exchange ties can be facilitated effectively by a single individual. In Figure 4.6, it can be seen that actor a5 is already least active in trading information as typically seen for individuals of similar occupation. Seemingly, the sub-network to contractors already draws upon actor a5 and may lower the actor's involvement with the core of network $A - \mathcal{X}_1$. The situation is illustrated in Figure 4.25.

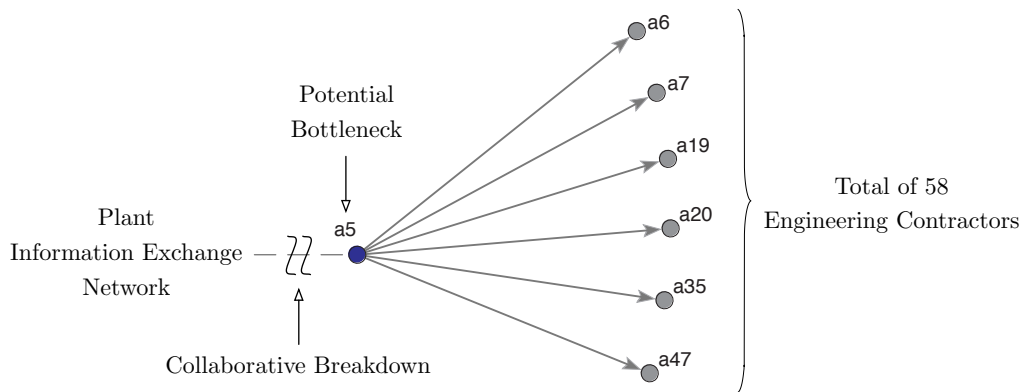


Figure 4.25: Collaborative breakdown resulting from bottleneck a5 in $A - \mathcal{X}_1$.

The findings support the suspicions that the actor a5 may become a bottleneck in information flows to contractors that most certainly exacerbates the management of change among the tasks that are facilitated by contractors. Albeit, actors that are key to physical asset care, and thus are key to the operation, remain in a contracting position. Consequently it appears problematic to retain the created competencies in the at the heart of the operation and in the engineering department. It is critical to question how the core competencies at the operation's base are sustained when key engineering skills are widely outsourced. The analysis clearly points towards a perilous management of key engineering tasks.

In Case Study *A*, no departmentalised PAM function exists. Optimisation projects in PAM are facilitated by the existing organisational structure. In fact, the responsibility for an improvement initiative typically lies with an employee from the technical department and projects are facilitated in collaboration with the engineering department.

The relationships between and within departments have been investigated using block models. Considering the blocks between the engineering department (i.e. class \mathcal{B}_2) and the technical department (i.e. class \mathcal{B}_4) it can be seen that the valued block densities are considerably lower than found for other relationships. The engineering and technical class realise the least amount of possible ties (see $\Delta_{\mathcal{B}_4 \rightarrow \mathcal{B}_2}^V$ and $\Delta_{\mathcal{B}_2 \rightarrow \mathcal{B}_4}^V$). Apart from this, it can be seen that the engineering class distributes the smallest share of its information supply to the technical class (see $p_{\mathcal{B}_4 \rightarrow \mathcal{B}_2}$). When the relationships involving the management class are excluded from the analysis, the technical department and engineering even trade the least information compared to all other classes (see $P_{\mathcal{B}_4 \rightarrow \mathcal{B}_2}$). Apart from that, engineering merely obtains marginal advice in decision making from the technical department (see $\Delta_{\mathcal{B}_2 \rightarrow \mathcal{B}_4}^V$ in \mathcal{X}_4). The mutual relationship of the engineering and technical department is significantly weaker than seen between other classes. There is strong evidence that the two departments are most distant from each other. A silo mentality appears to surface.

In addition, the block model for $A - \mathcal{X}_5$ indicates minimal interaction in decision approval. The entire interaction between the classes is virtually accountable to three individuals. These individuals are the metallurgist a1 and the two engineers a15 and a45. Moreover, the organisational chart shows that a45 is an engineering specialist and a15 the corresponding foreman. The informal organisation does not show much evidence of decision approval between the two departments and the little visible interaction refers to a more special engineering field than collaboration between the classes. Therefrom, it may be derived that decision rights regarding collaborative improvement projects are either allocated to actor a1 or are elevated to a third party, possibly the plant manager. As the collaboration between the two departments is substandard, the latter case appears to be more plausible. Hence, there may also be problems in decision making that can affect the strategic cooperation between the departments. In the case that the authority regarding strategic PAM initiatives is allocated to a third party, this entity may become a coordinator between the two departments, see Figure 4.26. This may not only be ineffective for making decisions but also entices the two departments to forfeit collaboration and behave like silos.

The collaboration between the engineering and technical department is largely absent. However, the departments' cooperation in strategic initiatives is vital. In combination, the findings may firstly deteriorate the success of single projects but eventually constrain the PAMSE.

The analysis results highlight collaborative breakdowns that can severely impair PAMSE. Actor a5 may turn into a salient bottleneck that is the only channel of information to numerous engineering contractors whose involvement can be critical in

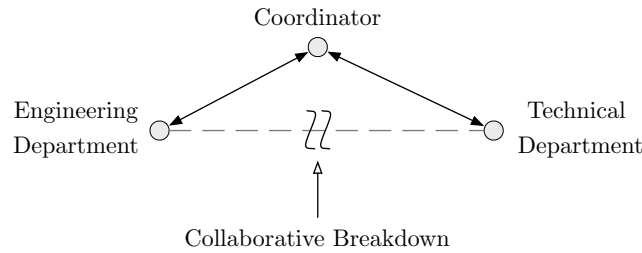


Figure 4.26: Collaborative breakdown between classes \mathcal{B}_2 and \mathcal{B}_4 .

PAM initiatives. The cooperation between the technical and engineering department is deficient. This is especially worrying because strategic initiatives are supposed to be facilitated conjointly between the two departments. The SNA pinpoints probable areas of concern in the plant's working structures where intervention efforts are required to create the needed connectivity and remove constraints in the PAMSE.

Excessive Intradepartmental Cohesion

(Consolidation of results no. 15, 16, 18, 22 and 23. See Appendix F)

The engineering department and its employees are a major building block for PAM. A good portion of the diverse PAM skills are inherent in this department. Redundancies and unclarity in roles and responsibilities in this department may hamper the PAM initiatives that have to push through this structure.

The analysis of Case Study A repeatedly indicates a high internal connectedness of the engineering function. Despite being three times the size of the production class; the engineering department's internal density in information exchange confidently outscores the production class (see $\Delta_{\mathcal{B}_2 \rightarrow \mathcal{B}_2}^V$). Additionally, Table 4.7 elucidates that roughly a third of all information exchange interaction is taking place within the engineering class (see $P_{\mathcal{B}_2 \rightarrow \mathcal{B}_2}$). In the first place, the findings suggest a strong collaborative environment that can be beneficial to the PAMSE but may be driven by problems that the department experiences. A strong interdepartmental cohesion also permeates both relations of decision making. As seen in relation \mathcal{X}_1 , the internal connectedness of the engineering class surpasses the value of the production class also in relation \mathcal{X}_2 . Further, the bulk of resource exchange as a proportion of the total interaction within the entire network is persistently found within the engineering class (see $P_{\mathcal{B}_2 \rightarrow \mathcal{B}_2}$ for \mathcal{X}_r). Special attention must be drawn to the influence of $P_{\mathcal{B}_2 \rightarrow \mathcal{B}_2}$ in relation \mathcal{X}_5 . Correspondingly, as much as 23.84% of all decision approval interaction occurs within the engineering class.

The findings are accompanied by a space in the network, where particular unclarity or inefficiency in decision making is present. The analysis for cohesive subgroups reveals a strong component in the approval network, see Figure 4.22. The component is comprised of five individuals from the engineering class and a single actor from the production and technical department, respectively. Within this subgroup actors are highly dependent on each others approval in making decisions. Furthermore, the subgroup contains four cyclic components, where two actors rely on their mutual approval. Three out of four cyclic approval processes exist between actors from the engineering class.

The SNA points towards very close collaboration within the engineering department. At the same time the analysis highlights an alarming cohesion in decision making that may result from inefficiencies or unclarity in decision processes and may cripple the execution of strategic initiatives through the department. In search for hints to a plausible explanation for this state, the relational structure of the plant draws the attention to two major issues. Earlier results show that the vacant position of a second section engineer may impose indirection into the reporting structure within the engineering class. This may result in a clutter of relationships between employees and disrupt formal processes. In addition, the analysis highlights actors within the engineering department that consistently lack connectivity in comparison to other actors.

The engineering class contains the actors a14 and a48 who facilitate the plants maintenance planning. The degree distribution and other centrality measures indicate the actors seclusion in the plan's networks. Both actors appear in the third quadrant in degree scatter plots. Thus, the maintenance planning function appears secluded in information exchange, passive in trading decision advice and moderately active in decision approval interactions. Closeness and betweenness measures clearly illustrate the actor's peripheral position in relation \mathcal{X}_1 and \mathcal{X}_4 . Additionally, the positional analysis suggests a structural similarity of both actors. Because it was assumed that the maintenance planning for both process sections is split between the two maintenance planners; this finding is worrying. The maintenance planning function does not only have inferior connectivity but also shares a common neighbourhood, further limiting their influence reach.

The maintenance planning function is expected to take a coordinating role in scheduling the myriad of engineering jobs at both process sections and it is startling to discover a debilitated activity of this function that permeates every relation. The marginal and homogeneous activity of the maintenance planners suggests a largely

reactive mode of addressing engineering tasks that may even be coordinate among engineers themselves. A dysfunctional maintenance planning may contribute and partly explain the extraordinary connectedness within the engineering department. The debilitated maintenance function possibly forces foremen into self alliance in coordinating maintenance tasks, creating additional cohesion. There might be a substantial opportunity in scrutinising the current state and effectiveness of maintenance planning. As well, there can be value in assessing the allocation of decision rights and the design of decision and business processes within the engineering department. Corrective actions that follow from these results may produce key contributions to the improved functioning of the engineering department and remove current constraints, in decision dynamics. The optimised function of the engineering class as a key role in PAM may ultimately undergird the execution of the PAMS.

Overview

The informal working dynamics shed light onto potential problems for future PAM initiatives. The results consolidate findings that stem from various measures investigating the informal networks in Case Study A. Centrality measures showcase actors whose position enables them to take disproportional effect on the network to compellingly influence the execution processes but emphasise that actors can just as well become overloaded and be a choke for working dynamics. The visual analysis and blockmodelling of networks demonstrates where interventions are needed to facilitate the required connectivity between strategically important groups. Furthermore, the analysis points towards potential redundancies and inefficiencies within key functions for PAM. The results render three primary constraints in PAMSE: *overloaded key actors*, *collaborative breakdowns* and *excessive intradepartmental cohesion*.

The analysis results deliver comprehensive insight into constraints in PAMSE at the research site. In order for results to materialise, they have to be scrutinised against the experience of the individuals that build the subject of analysis. In a next step the research site is revisited and confronted with analysis results in order to test their validity.

4.5.8 Validation of Results

This section evaluates the SNA results. For the validation of results the research participants have been revisited. In order to confront and question research participants with findings, they have been purposefully selected and contacted using email and telephonic interviews. Individuals have been selected in a way that best ensures the confidentiality of the participants' personal results. In some cases, the

analysis points towards specific actors that do not perform in a way that they were expected to. Because a validation of an actor specific underperformance is very sensitive, this thesis desists from the validation of these findings. In correspondence the presentation of results, this section will place its focus on the validation of the most significant results. As practiced for the secondary results, an abridged discussion of the entirety of result validations is provided in Appendix G. The summary provides a short comment on each finding and attributes each validation attempt with a condition. Findings that receive agreement by research participants are attributed with the condition “TRUE”. When findings receive disagreement by research participant, they are attributed with “FALSE”. If statements by research participants contradict each other, a finding is labelled with “INCONCLUSIVE”. In the following sections, the validation of results is discussed. The discussion is presented against the background of the established areas of concern: *overloaded key actors*, *collaborative breakdowns* and *excessive intradepartmental cohesion*.

Validation: Overloaded Key Actors

(Validation of results no. 2, 6, 7 and 8. See Appendix G)

The results pointed out that actors a13, a26 and a30 are highly central actors in the plan’s informal networks that may unintentionally become bottlenecks if overloaded. Specifically, it was found that the engineering specialist, a26, is characterised by a informal position that resembles a section engineer. Actor a13 raised particular concerns in being overloaded with decision approval requests from others.

The position for a second section engineer has been vacant for almost eight months. It has been confirmed that actor a26 fulfils (at the point of data collection) the role of a second section engineer. The double role lead to significant work overload of a26 and as a result the responsibilities have recently been reallocated to actor a34⁹. Apart from that it may be noted that actor a26 is involved in resolving diverse problems at the production process, this additionally boosts his connectivity and burden. Additionally, a work overload of actor a30 was confirmed. As it was suspected, the overload primarily springs from the vacant position of a second section engineer. The plant is too big as that one engineer could effectively cope with all legal compliances on his own. Only the engineer has the authority to make decision that involve legal requirements. These tasks are the main reason for the actor’s high connectivity and encumber his role. Apart from this, it was found that departments

⁹The analysis of relation \mathcal{R}_1 suggests that actor a34 is already in a very central position. From an SNA point of view, it may be said that this decision may shortly lead to a similar overload of actor a34. This view is shared by research participants.

frequently assign tasks to engineering that do not fall into its responsibility. The decisions in these situations also necessitate the involvement of a30. Actor a30 is strikingly overloaded and does not have any capacity for additional improvement projects. However, management are currently considering to restructure the plant in a way that the role of the engineer is limited to “high-level” involvement and legal issues. The restructuring efforts aim to distribute workloads more appropriately within the engineering department. It was found that subordinates of a13 frequently do not take full responsibility of their duties and elevate decisions to actor a13, this results in an increase in the “unnecessary” workload on a13. Because the plant’s systems are problematic, the respective heads of departments significantly draw on support and guidance from the plant manager and most often expect a13 to make decisions on their behalf.

The validation delivers comprehensive confirming evidence for the findings that were drawn from the SNA. The positional analysis captures the informal role of a26 that clearly deviates from the formal organisational hierarchy. It has been confirmed that actor a26 is significantly overloaded. The actor a30 is strikingly overloaded and is working over capacity. The actor is encumbered and not capable to facilitate extraordinary tasks. In fact, as it was suspected, decisions are frequently elevated to actor a13. Currently, the plant manager is not working at the optimum because the actor is tied up in taking responsibility for extraordinary decisions that get passed on by other individuals. The fact that a30 is the only actor to address decisions that have legal implications and decisions are frequently elevated to a13 explains the high centralisation of the decision making network. The SNA achieved to highlight problem areas that resemble the working dynamics at the plant and may constrain the execution of the PAMS.

Validation: Collaborative Breakdowns

(Validation of results no. 4, 5 and 19. See Appendix G)

The analysis points towards two main areas of concern, where collaborative breakdowns can impede PAMSE efforts. Firstly, the actor a5 emerges as the only link to numerous contractors that facilitate engineering tasks and is prone to becoming a bottleneck in information flows. Secondly, the mutual relationship between the engineering and technical department is lacking, though the two departments are meant to facilitate strategic PAM initiatives in collaboration.

The validation confirms a reporting structure of engineering contractors as it is depicted by the SNA. Actor a5 is the single point of reference for the engineering

contractors at process section two. It is acknowledged that actor a5 is accomplishing a difficult role in managing as many contractors. Potential shortcomings from this setup were not comprehended by the plant, yet. The validation of findings resulted in an important pointer for management. As a result of the debrief, management recognised the danger of the reporting structure and is investigating this issue.

Apart from this, it is recognised that the outsourcing of key engineering competences is perilous. When the operation was commissioned the engineering labour was under resourced due to unreasonable assumptions. Maintenance activities were not facilitated adequately. Therefore, it was decided to incorporate the assistance of contractors. The plant is aware of the inherent risk in outsourcing key skills and aims to increase engineering staff and to terminate outsourced activities.

The SNA correctly depicts two problem areas surrounding engineering contractors. While the risk in outsourcing key skills is recognised by the plant's management, the potential bottleneck in information flows at actor a5 was not understood.

The validation confirms a lacking interaction of the engineering and technical department. The unhealthy relationship is a traditional feud at the plant. It appears that the main clash results from the mindset of the two departments. The technical department is driven by a mindset of efficiency, while engineers focus on availability in order to serve production. The two mindsets undermine each other and negatively effect the relationship between departments. It is acknowledged that the cooperation of the two departments is vital and communication is substandard at present. The relationship is a serious concern and it is strived for a resolution.

The obtained results were comprehensively validated. The SNA achieved to adequately pinpoint two areas in the plant's informal networks, where considerable risk is inherent and collaborative breakdowns imperil PAMSE efforts.

Validation: Excessive Intradepartmental Cohesion

(Validation of results no. 15, 16, 18, 22 and 23. See Appendix G)

The engineering department stands out as the department with a particularly high internal connectivity. While the intradepartmental cohesion can be beneficial for information sharing, it can significantly obstruct decision processes.

The validation confirms that that the vacant position of a second section engineer imposes indirection into the reporting structure. The analysis suspected that the reporting structure and processes within the department are cluttered. The validation

shows that the compliance to formal processes is lacking. Individuals do not stick to procedures making the interaction within the department ineffective. Additionally, it has been pointed out that other departments frequently assign tasks to engineering that do not fall its responsibility. The decision for such projects pass through the department and have eventually be taken by the single section engineer a30. These request may additionally add to the engineering department's cohesion.

Despite the above, the results highlight a debilitated maintenance planning function that possibly forces the foremen into self alliance in coordinating maintenance tasks. The suspected dysfunctional state of the maintenance function has been confirmed. The communication with the maintenance planing is insufficient and there is little agreement about communication processes. It appears that there is a pressing need to revise the work management and the handling of job carts. The work management can not keep up with the timeliness that is required by engineers and foremen and therefore they are forced to take alternative planning action. Currently, the maintenance planning function is dysfunctional and can not effectively assist the engineering department. This results into a proactive maintenance planning by various employees. The absence of functioning work management boosts the internal connectivity of the engineering department.

The obtained results were comprehensively validated. The results from the SNA adequately reflect present shortcomings that affect the engineering department and induce extraordinary connectivity amongst employees.

Validation: Methodological Considerations

In closing the validation of results, it is expedient to provide some significant remarks regarding the validity of the developed application methodology.

The developed application methodology was successfully applied in Case Study A. The design of the survey methodology enabled the free recall of actors. It was the intent to establish a diaphragm for the study boundary that allows for the analysis of a network's context. Case Study A demonstrates that the analysis captures additional actors who were no included on the fixed list (engineering contractors). These freely recalled actors frame the network under study. The use of a fixed list survey methodology would have failed to capture and contextualise the problems that surround actor a5 in findings no. 4 and 5. The use of an expanding selection methodology emerges as an especially valuable methodological decision. Apart from that, the application methodology considered the bias of SNA towards more stable

relationships. This consideration is indispensable in order to understand the relational structure that ties the actors a30, a37, a44 and a50, see findings no. 3 and 9. It is important that the application methodology prepare the analyst for the long-term bias of SNA. Hence, the SNA application methodology was applied successfully and comprises of elements that are of distinct importance.

4.6 Chapter Summary

Chapter 4 utilises the previously developed SNA application methodology at two suitable research sites. In essence, the chapter applies a SNA in two case studies at asset-centric organisations in order to test the method's ability to highlight primary constraints in PAM. At the outset of the chapter, the application framework is established. The chapter outlines the preparation process that is followed in order to engage in a research partnership with organisation. Methodological modifications, adopted in order to accommodate research partners, and assumptions that form the basis of the analysis are introduced. After the presentation of the analyses' preliminaries, the two Case Studies "R" and "A" are introduced and discussed in succession.

Case Study *R* was facilitated in cooperation with a heavy mineral mining company, managed by Rio Tinto Plc. The case study did not yield a sufficient questionnaire return rate. Due to the lacking commitment of research participants, the research process was discontinued. Nevertheless, the course of the research process motivated the notation of some important results. The experience of SNA research in Case Study *R* underscored the importance of energetic support by a senior sponsor for the network study. Additionally, the organisational culture may determine the eagerness of research participants to participate in the study. Establishing commitment among research participants is supposedly the most important factor for the success of a SNA. In Case Study *R* information regarding research participants was merely provided via email. This may also have lowered the commitment of survey participants. However, a non supportive and defensive organisational culture could also significantly hinder this venture. The research process, and most importantly, the potential benefit from the SNA application, has to be thoroughly explained to the involved individuals on every organisational level. A lack of participant motivation can cripple the data collection and eventually stall the research process, as seen in Case Study *R*.

Case Study *A* was executed in collaboration with AAPL. The study received considerable support by AAPL and was conducted in collaboration with the ACRG. The result of the personally administered survey was that the research participants

were sufficiently motivated. Moreover, the organisational attitude at the research site was supportive of the research process. The questionnaire return rate was thus 100% and a thorough SNA of the plant was conducted. The SNA captured informal working dynamics at the research site and delivered comprehensive insight into potential constraints in PAMSE. The presentation of results focussed upon the findings that were expected to have the utmost impact on future PAM aspirations. The results consolidated different findings to primary constraints in PAMSE. The results rendered three primary constraints in PAMSE: *overloaded key actors*, *collaborative breakdowns* and *excessive intradepartmental cohesion*.

Centrality measures look specifically at actors whose position equip them with disproportional power to compellingly influence other network members. Working through these individuals is essential to the PAMSE. The analysis makes the important point that the plant's key actors are either prone to becoming overloaded or are already working beyond their capacity. They may be in pivotal roles but can just as well end up choking the effectiveness of the organisation by blocking information flows, slowing decision making and eventually constraining the PAMSE. *Overloaded key actors* are a primary constraints in PAMSE.

The visual analysis and blockmodelling of networks shows where interventions are needed to facilitate the required connectivity between strategically important groups. Two main areas of concern are evident, where a collaborative breakdown can significantly obstruct the execution of the PAMS. Actor a5 emerges as the single channel of information to as many as 58 members of the engineering contracting staff. The actor builds the critical path for information to reach engineering contractors. There is an inherent risk in this structure because the single channel of information can easily be overstrained and lead to actor a5 obstructing the information flow. In addition, the actor may distance himself from the plant's core, because the subnetwork to peripheral engineering contractors draws on the actor's capacity. The above would result in the loss of the tie to staff who facilitate fundamental tasks at the plant, establishing a major impediment for PAMSE. Apart from this, it was shown that collaboration between the engineering and technical department is lacking. The functional relationship between the two departments is indispensable for the successful execution of strategic PAM initiatives. The collaborative breakdown between these departments is a salient constraint in PAMSE. *Collaborative breakdowns* between the plant and its engineering contractors, as well as between the engineering and technical department, are primary constraints in PAMSE.

Furthermore, the analysis points towards potential redundancies and inefficiencies within the key function of engineering. The engineering department attracts attention because it shows an obviously high internal connectivity. The excessive density within the engineering department is firstly attributable to a dysfunctional state of the maintenance planning function, that forces foremen and engineers into self alliance and close collaboration. Secondly, the engineering department makes up a large part of a strong component in the decision approval network. This component consists of a space in the network, where considerable redundancies and non compliance to business processes undermine effective work processes. At the expense of the effectiveness of the engineering department, the combination of these drawbacks induces unclarity of responsibilities and leads to inadequate collaboration among the employees. The *excessive interdepartmental cohesion* of the engineering department is a primary constraint in PAMSE.

In order to validate the derived results, they have to be evaluated by the individuals that form the subject of the analysis. The research site was revisited and individuals were confronted with the analysis results, in order to test their validity. Out of the original 24 findings, 19 findings were found to portray the actual situation at the plant. In terms of one of the findings, however, no conclusive validation was obtained because the statements made by interviewees were contradictory. In three of the cases, the thesis refrained from validating the findings due to the sensitivity of the subject. Apart from this, it can be noted that the developed SNA application methodology was successfully applied at research site *A*. The failure to apply SNA in Case Study *R* may primarily be caused by a lack of commitment among the individuals that were selected for the study. It has to be acknowledged that this may partly be accountable to the research process. Apart from this, the SNA application methodology contains the relations \mathcal{X}_2 and \mathcal{X}_3 that have been found to be unfeasible for the practical application in either case study. In spite of this, the SNA application methodology contains elements that emerged to be particularly useful: these are the use of an expanding selection survey methodology and the consideration of SNA's bias towards more stable relationships.

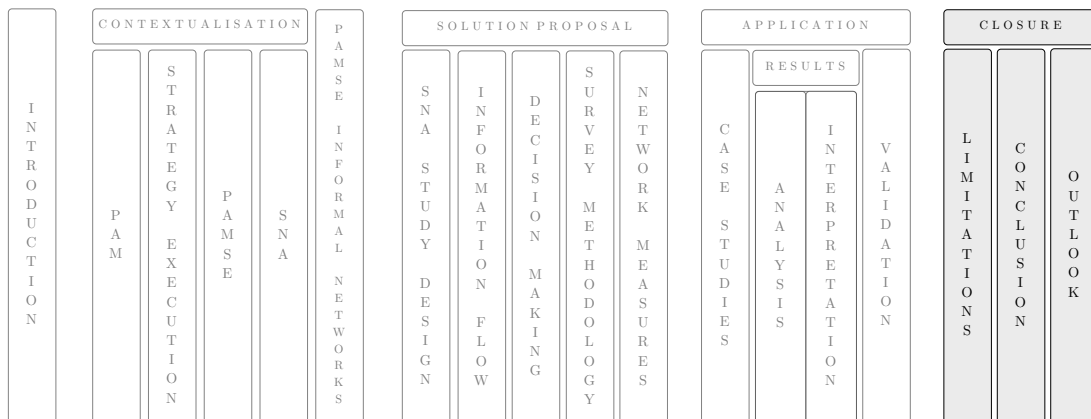
Above all, SNA was successfully applied at one research site, the SNA identifies *overloaded key actors*, *collaborative breakdowns* and *excessive intradepartmental cohesion* as primary constraints in PAMSE in Case Study *A* and the validation process confirms the presence of these salient areas of concern. Consequently, the research objectives six, seven and eight are accomplished.

Chapter 5

Closure

Chapter Aim:

The aim of Chapter 5 is to consolidate the research findings into a final conclusion. In addition, the chapter aims to point limitations of the study and recommendations for future research in SNA applications for PAM.



Chapter Outcomes:

- Limitations to this study.
- Final conclusion.
- Answer to the central research question.
- Result of testing the null hypothesis.
- Recommendations for future research.

5.1 Limitations

The study of a SNA application in PAM in this thesis was exposed to several limitations. These are made explicit below. The assumptions regarding the SNA, that were stated in Chapter 4, are not repeated at this point.

- (1) In some asset-centric organisations, practice may not coincide with theory. The benefit of the SNA is limited by an organisation's compliance to PAM, as characterised in this thesis.
- (2) It may be argued that not all information is exchanged between individuals. The internet or organisational databases are examples of alternative sources of information that are not considered by the analysis. SNA is limited to the interactions between people.
- (3) The enumeration of the relevant actors and interpretation of their roles is highly dependent on the quality of organisational records. Incorrect information may cause mistakes in the interpretation and thus limit results.
- (4) Survey participants may anticipate certain results and try to give a good impression in the analysis. The SNA is therefore limited by the truthfulness of responses.
- (5) Structural calculations may be susceptible to the influenced of responses from particular actors, see result no. 24 in Appendix F. Single actors may limit the benefit of some network measures.
- (6) Benchmarks for the produced network measures are not readily accessible. The analysis results are based on relative comparisons within the studied organisation. This may limit the researcher's interpretations and judgement.
- (7) SNA yields results that only become meaningful through the interpretations by the analyst. The quality of interpretations may limits the benefit of the SNA.
- (8) All research participants were assured that their identity and personal results would remain confidential. The research participants have to be protected at all times. Therefore, troublesome actors can not be approached directly in order to take corrective action. The confidentiality agreement with research participants limits the corrective action that can be taken.

The limitations of this study have been pointed out. Thus, the final conclusions can now be drawn. The following section reflects on the conducted research and draws the final conclusion of this study.

5.2 Conclusion

Chapter 1 introduced the research domain and the research question of this thesis. It was stated that the means to detect primary constraints in PAMSE are deficient. The inability to identify problems that hamper execution efforts is troublesome. This is especially so because strategies are prone to failure and because successful PAMSE is an important value driver for asset-centric organisations. In order to address this drawback, the purpose of this thesis was to investigate SNA as a method to map the primary constraints in PAMSE. With regards to this goal, nine research objectives were defined of which eight have been achieved throughout the first four chapters of this thesis, see Table 1.3.

The literature review in Chapter 2 was supplemented with the views from PAM practitioners. Consequently, the literature review did not only establish the fundamentals of PAM, PAMSE and SNA, but also contextualised the challenges faced in PAM with the matching capabilities of SNA. The constraints that are deemed to stifle the PAMSE were thus singled out. It was found that defects in information flow and decision making are the primary constraints in PAMSE. As a result of this finding, Chapter 3 developed a SNA application methodology that focussed on questioning the informal networks of PAM, concerning the identified areas of concern. In Chapter 4, the developed application methodology was applied to two research sites in the South African mining industry. The case studies produced a number of results, of which, the results from Case Study *A* were validated through the dialogue with research participants. The final research objective is to draw conclusions from the conducted research that answer the central research question of this thesis and test the defined null hypothesis:

H_0 : Social network analysis can not be used as a method to map primary constraints in physical asset management strategy execution.

In Case Study *R* no SNA could be conducted. Due to the insignificant responses from survey participants, the SNA study was discontinued during the data collection process. The experience gained from the research process in Case Study *R* suggested four important pre-requisites for the success of a SNA application, these are:

- Energetic senior sponsorship.
- Adequate motivation of employees.
- A supportive organisational culture.
- Personal involvement of the researcher.

In Case Study *R* the above prerequisites were only partially present, which was supposedly the reason why the research had to be discontinued. On the contrary, the above conditions were fully present in Case Study *A*. Presumably as a consequence thereof, the developed SNA application methodology was executed successfully and no drawbacks were experienced during the research process. In Case Study *A*, the SNA achieved to discern a number of factors that could risk the successful execution of the PAMS. Most importantly, the SNA mapped three primary constraints in PAMSE that were confirmed by the validation process, these are:

- Overloaded key actors.
- Collaborative breakdowns.
- Excessive intradepartmental cohesion.

Case Study *A* compellingly demonstrated that SNA can be used as a method to highlight primary constraints in PAMSE. Nevertheless, the successful utilisation of SNA may be highly dependent on the stated application pre-requisites. This thesis comes to the conclusion that SNA *can* be used as a method to map primary constraints in PAMSE and emphasises that there are important prerequisites that have to be established to reach the successful application of SNA. Consequently, the null hypothesis is rejected.

The rejection of the null hypothesis accounts for the achievement of the final research objective. Every research objective of this thesis was accomplished, resulting in a comprehensive answer to the stated research question. The thesis closes with the provision of recommendations for future research in the following, final section.

5.3 Outlook

During the research process some considerations emerged that may be worth investigating further. The recommendations for future research encompass four suggestions:

- (1) The next logical step to take after this study of SNA, is the development of plans to improve the informal networks in Case Study *A*. On the basis of the results from this thesis, the plant management may take corrective action in order to resolve the highlighted constraints. After improvement plans have been implemented and an adequate period of time has elapsed, a second SNA may be conducted. Important to remember at this stage is that the long-term bias of SNA requires a considerable time lapse before a second SNA can capture changes

in the informal networks. This second SNA may reveal if the identified defects in the network could be eliminated.

- (2) In a SNA the collection of network data can be sensitive to the extent that it reveals how “well” individuals perform and whether they fulfil the roles and responsibilities that are assigned to them adequately. Future research may investigate whether a SNA can be applied without the consideration of confidentiality. An open and candid discussion of results from a SNA may realise the method’s true potential to increase the effectiveness of working structures.
- (3) For the purpose of this study, single plants were analysed. However, Section 3.5 showed that the boundary of a SNA is scalable. Therefore, future research may attempt to use SNA in order to capture the informal networks that connect multiple plants. This could potentially show problems of PAM on a higher level and inform the dissemination of an organisation’s PAM approach to an organisation’s different operations.
- (4) Over time, it may be beneficial to gather the results from different SNA studies in PAM and to make the results accessible to other network researchers. This may enable the comparison of network measures across studies and inform future investigations of the interpretation of study results.
- (5) The analysis of Case Study *A* illustrated that with increasing density of networks, some network measures become problematic. Furthermore, the exploratory analysis of networks is very dependent on the properties of the network under investigation. Nevertheless, it may be valuable to attempt the development of a guiding model for the selection of measures for future network studies in PAM.

The recommendations listed above could provide interesting opportunities for future research projects, involving SNA applications in PAM.

Appendices

Appendix A

The 17 Fundamental Traits of Effective Strategy Implementation

See next page.

APPENDIX A. THE 17 FUNDAMENTAL TRAITS OF EFFECTIVE STRATEGY IMPLEMENTATION

| RANK | Organisation Trait | Strength Index (out of 100) |
|---|---|-----------------------------|
| 1 | Everyone has a good idea of the decisions and actions for which he or she is responsible. | 81 |
| 2 | Important information about the competitive environment gets to headquarters quickly. | 68 |
| 3 | Once made, decisions are rarely second-guessed. | 58 |
| 4 | Information flows freely across organisational boundaries. | 58 |
| 5 | Field and line employees usually have the information they need to understand the bottom-line impact of their day-to-day choices. | 55 |
| 6 | Line managers have access to the metrics they need to measure the key drivers of their business. | 48 |
| 7 | Managers up the line get involved in operating decisions. | 32 |
| 8 | Conflicting messages are rarely sent to the market. | 32 |
| 9 | The individual performance-appraisal process differentiates among high, adequate and low performers. | 32 |
| BUILDING BLOCKS: Designing Information Flow <input type="checkbox"/> Clarifying Decision Rights <input checked="" type="checkbox"/> Aligning Motivators <input checked="" type="checkbox"/> Making Changes to Structure <input checked="" type="checkbox"/> | | |

(a) Traits 1-9.

| RANK | Organisation Trait | Strength Index (out of 100) |
|---|---|-----------------------------|
| 10 | The ability to deliver on performance commitments strongly influences career advancement and compensation. | 32 |
| 11 | It is more accurate to describe the culture of this organization as "persuade and cajole" than "command and control." | 29 |
| 12 | The primary role of corporate staff here is to support the business units rather than to audit them. | 29 |
| 13 | Promotions can be lateral moves (from one position to another on the same level in the hierarchy). | 29 |
| 14 | Fast-track employees here can expect promotions more frequently than every three years. | 23 |
| 15 | On average, middle managers here have five or more direct reports. | 19 |
| 16 | If the firm has a bad year, but a particular division has a good year, the division head would still get a bonus. | 13 |
| 17 | Besides pay, many other things motivate individuals to do a good job. | 10 |
| BUILDING BLOCKS: Designing Information Flow <input type="checkbox"/> Clarifying Decision Rights <input checked="" type="checkbox"/> Aligning Motivators <input checked="" type="checkbox"/> Making Changes to Structure <input checked="" type="checkbox"/> | | |

(b) Traits 10-17.

Figure A.1: The 17 fundamental traits of effective strategy execution.

Adapted from Neilson et al. (2008).

Appendix B

Expert Interviews: Physical Asset Management

See next page.

B.1 Interview with Mr. Grahame Fogel

Interview Details

| | |
|-------------|-----------------------|
| Name: | Grahame Fogel |
| Occupation: | Consultant & Director |
| Company: | Gaussian Engineering |
| Date: | 2012-03-14 |
| Time: | 17:40 - 18:10 |
| Place: | KwaZulu-Natal |

Author (A) and Mr Fogel (F): Welcoming...

A: How long have you been involved in the field of asset management?

F: "Twenty-five to thirty years."

A: How would you define and explain PAMS?

F: "I think it is the sets of activities that are put into place to consistently drive performance of assets through their life cycle."

A: How would you explain the execution of the strategy - what does that entail?

F: "I think strategy consists of two things. It consists of the formulation, which is the decisions that come together to form some kind of plan and a plan only becomes live once you put it in place and execute it. Strategy execution is the living embodiment of what you intend to do within the plan."

A: Would you say that it is translation of your high-level aim into sub-initiatives through which you want to achieve your plan?

F: "Correct. You have a high level objective which then gets divided up into lots of lower level objectives. These are executed in coordination with specific timing, which when put together create the outcome that you require."

A: Do you think that the balanced scorecard depicts the process in terms of asset management quite well?

F: "I think it does, to me also strategy depends on the amount of empowerment you have within an organisation and empowerment also includes knowledge. So if you are minimally employed with low knowledge then you need a strategy to reach even simple objectives. But if you are the managing director of the company and you have got all the resources you need and lots of knowledge you don't need a strategy - just action things. So it depends where you are in the organisation whether you need a strategy or not. To me, what defines a strategy is that you have got a high level outcome which is highly leveraged, it has to give huge benefits because a strategy is complex to put in place and very complex to invoke. It is really difficult to do - by definition it is difficult to do. If it was easy to do, you just do it - it becomes an action - you just go and do it. So strategy has to have a highly leveraged outcome, it has to be difficult to achieve because otherwise it just becomes a plan. It takes coordination, often of scarce resources and the most scarce resource is often time and you better be rewarded by it because it takes a lot of effort and energy."

A: So you are actually saying that the resources that you need to execute it are more important than those you need to plan it?

F: "Correct, because planning is easy. Formulation of a strategy takes a couple of weeks. If we want to go and do the smelter tomorrow, put a strategy for the smelter, we can have a strategy in two days. But to execute the strategy will probably take two years. I think also this now is a keypoint: you can have a 75% good strategy which is a 100% well executed and you get fantastic effects. You can have a 100% good strategy which is 50% well executed and you get nothing - so it's all in the execution."

A: In your experience, what are the biggest problems in the process of execution?

F: "I think people don't understand the strategic process properly and don't have the confidence to do it, so that can be an obstacle. They don't have staying power to see it through and they are not adequately sponsored by the organisation, and not given enough space and resources to execute the strategy. Those are three reasons."

A: Would you say that is a problem of communication?

F: "It is a communication problem but also quite often people just don't execute properly. If you are looking at Kaplan and Norton and the balanced score card, they say that 90% of organisations fail to execute their strategy properly and that is a huge failure rate. They also name the reasons for failure."

A: Are you confident that the literatures reasons are transferable to the asset management environment?

F: "I would say yes they are. One of the things about asset management is consistently that they do not budget properly for it, under financed, under resourced."

A: I would like to refer to other findings of the literature. It is postulated that for effective execution everyone should have a good idea of the decisions and actions of which he or she is responsible. Do you think that coordination and role definition is important?

F: "Correct, absolutely. You know, in strategy execution the formulation that I use is: each component of the strategy, sub-strategy in other words, has what I call an owner and an owner is somebody who is a single point of accountability for its execution and a owner need to be two things. He needs to be willing and capable of executing strategy. Then an owner can have people that work with him to execute it - you know teams, consultants who ever it is who help him, those are agents of the owner. But the owner is responsible for achieving the milestones or goals or whatever it is of that sub strategy. To me the most important thing is that you have a really good and strong person in driving strategy execution - then it happens."

A: I perviously explained the network analysis to you. Would you see a benefit in putting this network analysis over the pool of people that would be involved in the main initiatives and you identify the strong people?

F: "For sure! Absolutely. Especially if you get a quick diagnostic - early in."

A: Prior to execution?!

F: "Prior to execution and during execution."

A: Are there any tool to overcome those problems as in interpersonal relationships?

F: "Not that I know of. I can say that when I did strategy execution I put together very strong accountabilities."

A: Well then it obviously would be nice to have a method to decide whom to assign from an informal network perspective.

F: "Correct."

[The interview ends with formalities; thanking the interviewee for his time and insight.]

B.2 Interview with Mr. Newman

Interview Details

| | |
|-------------|--|
| Name: | Mr. Newman (The interviewee's name is arbitrary to ensure confidentiality). |
| Occupation: | Manager Asset Management & Manager Reliability Maintenance |
| Company: | Rio Tinto |
| Date: | 2012-04-26 |
| Time: | 07:30 - 08:30 |
| Place: | Confidential |

Author (A) and Mr Newman (N): Welcoming...

A: How long have you been involved in asset management?

N: "Okay, for asset management per se at this organisation, my only involvement in moving more into a defined state has only been this year and started july last year. Asset management has always been tossed around within the organisation for a number of years. But one needs also to quantify what transpired in the past in order to get us to take that leap forward."

A: In terms of the new understanding, the new definition of asset management - that you have now - what do you understand under asset management strategy?

N: "Okay, again the concept of asset management is also relatively new to most people. Previously the concept that was flying around was maintenance strategy and most of the organisations understood maintenance strategy and also it was easy for organisation to understand that concept because they could constantly palm it off to the maintenance individuals. Until obviously the evolvement of asset management strategy. Now one understands what the asset management strategy and the asset management process entails, it entails the whole lifecycle of the process from when a company or a project is initially thought of right through to its implementation, the whole management of it, to the resources that go into make it effective till eventually the equipment state or the company then dissolves it. "

A: Basically that what PAS 55 tells you?

N: "Yes."

A: Okay, then from that new shaped understanding of asset management, how would you define asset management strategy - because it is obviously not anymore solely maintenance?

N: "It's the evolvement of the involvement in a strategy that is aligned with the companies goals, because it's pointless having a strategy that doesn't have alignment with what the companies is trying to achieve. So that the strategy is around firstly around the companies goals and secondly the elements that dictate the life cycle of the whole equipment. And within that there is finer components that needs to be better defined of how we physically engage with the management of the assets."

A: That is exactly what I am interested in. I am saying that you can define your asset management strategy and now you have to translate it into projects and initiatives and execute those to actually achieve your higher aims.

N: "But one of the things that you also have to understand - that is pretty much within a broader context. But in an implementation context and within this policy you have 21 elements at this organisation. In PAS 55 you have 17 components. And to embark on a project of that nature - it is huge. So you then have to identify the gap within the organisation, we have to identify what is it we need to do and what is it that is going to do and where it is going to have the biggest impact. To a large extend it goes back into the maintenance topic, but without saying now that it is a maintenance strategy, you are still sitting with the broader concept of asset management. And that is the message that constantly needs to be promoted. Although the chunk sits with maintenance there are also other component that sit with production, what has to be very well defined and very well initiated - the very component there sits in operate for reliability. There is a lot that is maintenance related but there is also a lot that is in certain other sectors of the organisation - there are a lot more components. To a certain extend when you make your gap analysis you might as well outsource to contractors."

A: What do you expect or what do you know from your experience are the biggest constraints to actually execute the strategy in those projects. Say you want to improve one of those areas with certain project, what is the biggest hampering factor?

N: “One first need to understand where the biggest gap is. We have a pretty good understanding of what asset management involves, so it must be components that relates to the organisational goals of Rio Tinto. Asset management is integral to the organisation so now it is up to us to comfortably get the organisation aligned with the requirements. In doing the analysis and thats where the biggest issue comes, you got to understand what is it in the business that is efficient relative to your processes, to safety and to costs. Secondly there has to be that buy-in now, from the other sectors outside of the engineering sector. Remember, as we said initially, it was only an engineering initiative and now all of a sudden the General Manager (GM) of production has to adopt the body of a broader asset management. In the first meeting you could see that the production GMs were not fully throwing their weight behind it and eventually the Managing Director (MD) had to convince the GMs to submit to the asset management requirements. That’s were we got the buy-in. When we did our analysis we identified where the biggest gaps were. The biggest gap was sitting in the work management component, now coupled with work management is shut down management and as you can see - that is maintenance. So thats when we said we need to embark on an initiative that can give us that step change. ”

A: So you are saying that basically a big factor is the coordination between the different departments that are involved in asset management but sit in different “locations” in the organisation but that have to be treated as one?

N: “Yes, the differentiations. Correct.”

A: Is there anything else that you can think of in terms of as soon as you engage the projects?

N: “The first step was to get that buy-in and initially we didn’t get that buy-in from the higher levels. Now the next step is to obviously initiate that process.”

A: Let us focus on the initiatives that you did with the engineering teams. What were the big problem areas in actually driving change towards the new asset management understanding in those initiatives.

N: “Alright, what we must understand firstly relative to the structure that was formulated. Had I been in this position that I am now in the moment then I wouldn’t have been able to do what we have done. But the structure was different and it lent itself to one to be able to give you the authority to start the asset management. The position in that I was, was known as reliability and maintenance management. We

created a lot better structures to start influencing the plants and we created the one departmental asset management.”

A: Just for me to understand - basically the formal structure within the organisation didn't support your ambitions in asset management?

N: “Yes, but I had the influence via legal accountability for the plants. So when we started to engage with the plant we found that we have a reliability department and an asset management department and now we need to support the plants. So we said how do we support the plants? If they have a reliability engineer he or she as to go and investigate a problem at a plant but the problem needs to be substantial for him to be able to add value. He can't go there to investigate why a conveyor belt is failing all the time only to find that the belt is overloaded or the idlers are covered in sand, idlers are damaged and damaging the belt or idlers are missing, they are all maintenance items. So in order for us to be more effective as a reliability department, we need to do maintenance. And that is when my boss said: “Okay, that's not your job.” Well but I said, that if we don't do that we can't do our job firstly. Secondly it adds value to the bottom, to the output of the organisation and it made a serious impact. If you go to 2010 and look at oneplant's productions it just escalated from the initiative we put in place. But again, in doing that now you are interfering with someone else's domain and that's where you got the resistance. Then with other plants to do the same thing, the work became too much as well and we had to convince the GM and so on. So, the mindset already began to change with the plants.”

A: Would you say that the resistance we were now talking about, due to the intersection with different functional areas, is a problem of sharing views and communicating this idea of asset management?

N: “At that stage it wasn't even asset management it was just basic basic maintenance and operate for reliability. There was no appreciation for understanding the concept of asset management.”

A: Did you have the feeling that there is awareness for barriers resulting from the change of perception from basic maintenance towards the broader asset management concept?

N: “Well there is, but only very slowly. One must understand that we only now started with the initiative with two pilots and if you go to Plant A it is one mindset and if you got to Plant B it is a different mindset. But it is still a better mindset

than we had three years ago. So there is a very small appreciation but obviously a much bigger one at Plant A.”

A: What do you think is necessary to overcome barriers and spread the mindset.

N: “There are a couple of things. Obviously we run some training sessions with the people from Plant A to get them on board what they need to do. Those training sessions were expanded to other plants, we weren’t fully successful to get other plants in but we got quite a few. Then we have asset management training within RioTinto. Then you have obviously us, our department is formal since august but we have been in limbo because we didn’t have the right structure. So only since march we are officially the asset management department. Now it is up to us now to engage the various plants and to sell it.”

A: So the bottom line is information sharing?

N: “Correct.”

A: Would you be able to tell me the asset management strategy of your organisation?

N: “We are busy formulating that. But it will be based around a selection of the asset management components as identified by the Rio Tinto asset management manual.”

A: Okay and then those obviously break up into the initiatives?

N: “Correct. ”

[The interview ends with formalities; thanking the interviewee for his time and insight.]

B.3 Interview with Mr. Govender

Interview Details

| | |
|-------------|--|
| Name: | Mr. Govender (The interviewee's name is arbitrary to ensure confidentiality). |
| Occupation: | Technical Manager & Metallurgical Technical Engineer |
| Company: | Anglo American Platinum |
| Date: | 2012-06-15 |
| Time: | 08:30 - 09:00 |
| Place: | Confidential |

Author (A) and Mr Govender (G): Welcoming...

A: Are there any PAM projects running or planned for the concentrator?

G: "The one project is a normal asset optimisation project that we are busy with on a day to day basis at the mine and the second project is the long-term de-bottlenecking project which is the upscaling of the plant. I don't know which project you want to discuss, we can discuss both if you want to?"

A: Yes, let us start with the general asset management improvement project. In the context of my work at the university I am basically saying that if you define a asset strategy for a company I am interested how the strategy gets executed. And from my point of view the PAMS gets translated into specific activities that get steered throughout the organisations, so the current optimisation project very well falls into this view.

G: "Alright from my perspective as the Technical Manager of the plant, asset optimisation is one of my responsibilities. Basically, at the beginning of the year we review which project we do and select the ones that are expected to give us the biggest benefit. This year we have got two massive projects, the one is float optimisation for extra recovery and the second one is the de-bottlenecking of the secondary crusher circuit for extra production. So for asset optimisation on the plant we take each production unit - take what we have got - and try to get the most out of it.

The secondary crusher de-bottlenecking is split into two years and every two months we want to achieve something. We measure that on a monthly basis in meetings and discuss how the project has been progressing and track the Key Performance Indicator (KPI)s and how these are linked to production on a monthly basis on the plant. For that project we assess if the project has achieved its objectives in terms of its KPIs, if it has, we check the production on the plant and if the production on the plant has been above target that we have set, that project is given a benefit and vice versa. That is basically how we do it. The project will be run by a technical guy from an asset optimisation point of view and he will have the support of the engineering staff ranging from section engineers to the foremen.”

A: Has a PAMS been formulated for the concentrator, yet? Or is the strategy set by Anglo American Platinum for all its operations?

G: “No nothing, nothing that I have got hold of here.”

A: So at the moment you are targeting to generally get more effective and efficient?

G: “Yes.”

A: In your experience or what are you expecting to be the biggest constraints in implementing these projects, executing them in the organisation?

G: “The first major issue is skills on-site and it’s basically resources. We don’t have the people. You know we are a high production plant and run a single stream process, so as soon as there is a breakdown this becomes the focus. As a result we are acting short term and the long term projects are neglected. Even in our monthly meeting we don’t always have the key players. The guys that are actually doing the work; maintaining and changing the process; the engineering guys are not always in the meetings. Typically in the asset optimisation meetings you need the technical manager, who is running the project, the plant manager and the plant engineer - then the message gets spread across from that. The issue is that we look a lot on short-term.”

A: Okay, so you actually spend a lot of time with fire-fighting rather than engaging in long-term initiatives?

G: “Yes.”

A: How long has the project been running?

G: "It has been running since about September 2010, that's the continuous project, the big de-bottlenecking project has been running in the head office and I have just been assigned as the site-champion for the project."

A: What is the horizon for the project? By when are you trying to achieve the increase in production?

G: "The guys are still in the feasibility stage and at the moment there is very high pressure due to the platinum price. But the project is happening in the background. (Details of expansion project excluded)."

A: Will the change of the process be solely facilitated by contractors?

G: "It will be a complete Capital Expenditures (CAPEX) project. It will be the contractors' construction teams that build the plant. Decisions in the process will obviously be based on the limiting of downtime."

A: What do you think, how long will it take from assignment of contractors to actually running a stable process?

G: "That's a good question, I think the companies target is to make it happen by the end of 2013."

A: Do you have to significantly increase the employee numbers to run the expanded plant?

G: "That is definitely part of the scope and it will be discussed between the responsible person at head office, me and the human resources department. We will probably need a few extra operators, boilermakers and fitters and all of that has been part of the study."

A: Okay let me put that into the context of my study. From what I understand the strategy clearly is expansion of the production - going bigger.

G: "That's it."

[The interview ends with formalities; thanking the interviewee for his time and insight.]

Appendix C

Survey Participant Consent Form

See next page.



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**STELLENBOSCH UNIVERSITY
CONSENT TO PARTICIPATE IN RESEARCH**

Title: *Investigating Social Network Analysis as a Method to Map Major Constraints in Physical Asset Management Strategy Execution*

You are asked to participate in a research study conducted by Jan-Hendrik Baum (BSc. Industrial Engineering and Management), from the Department of Industrial Engineering at Stellenbosch University. You were selected as a possible participant in this study in the context of a case study contributing to a master's thesis with the above title.

1. PURPOSE OF THE STUDY

The purpose of the study is to investigate if social network analysis can be used to map major constraints in the execution of physical asset management strategy. Major constraints have been identified in information flow and decision making. Therefore social network analysis will be used to capture informal networks that visualise the dynamics of information flow and decision making inside the organisation.

2. PROCEDURES

If you volunteer to participate in this study, we would ask you to answer the questionnaire that contains the following questions:

Who do you typically receive work-related information from?
How often do you typically receive work-related information from this person?

Who do you typically rely on for advice prior to making decisions?
How often do you typically approach this person regarding advice in decision making?

Who do you typically rely on for approval in decision making?
How often do you typically approach this person regarding approval in decision making?

All questions may be answered by ticking applicable answers from the provided lists. As well, you may freely recall persons on the space provided after each question set.

We would like to ask you to fill in the questionnaire as soon as possible. The researcher will personally collect the questionnaire from you by today or tomorrow. The completion process should, in any case, not take longer than 10 to 20 minutes.

3. POTENTIAL RISKS AND DISCOMFORTS

To avoid any discomforts we will assure you that while information gained during the study may be published, you will not be identified and your personal results will remain confidential. Every participant will be protected by anonymisation.

4. POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

The results of this study might ease communication and enhance decision making in your working environment. Also the research might yield a tool to anticipate constraints to strategy execution in an asset management environment. However, there will not be any personal benefits for research participants.

5. PAYMENT FOR PARTICIPATION

Participation will take place on a voluntary basis and does not involve any payments.

6. CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained by holding data confidentially, in a secure place and in a password-protected computer in the form of hard and electronic copies. These data will be accessible to the researcher only.

While the information gained during the study may be published, you will not be identified and your personal results will remain confidential. Every participant will be protected by anonymisation.

7. PARTICIPATION AND WITHDRAWAL

You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. You may also refuse to answer any questions you don't want to answer and still remain in the study. The investigator may withdraw you from this research if circumstances arise which warrant doing so.

8. IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact

Principal Researcher:

Name: Jan-Hendrik Baum
Phone: 0027 744 50 42 74
Mail: 16825853@sun.ac.za

Supervisor:

Name: Dr. P.J. Vlok
Mail: pjvlok@sun.ac.za

Department of Industrial Engineering
Stellenbosch University
Private Bag X1 Matieland 7602
South Africa
www.ie.sun.ac.za

9. RIGHTS OF RESEARCH SUBJECTS

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research subject, contact Ms Maléne Fouché [mfouche@sun.ac.za; 021 808 4622] at the Division for Research Development.

SIGNATURE OF RESEARCH SUBJECT OR LEGAL REPRESENTATIVE

The information above was described to me by Jan-Hendrik Baum, in English and I am in command of this language or it was satisfactorily translated to me. I was given the opportunity to ask questions and these questions were answered to my satisfaction.

I hereby consent voluntarily to participate in this study. I have been given a copy of this form.

Name of Subject/Participant

Signature of Subject/Participant or Legal Representative

Date

SIGNATURE OF INVESTIGATOR

I declare that I explained the information given in this document to _____. [He/she] was encouraged and given ample time to ask me any questions. This conversation was conducted in English.

Signature of Investigator

Date

Appendix D

Research Ethics Committee Approval Notice

See next page.



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Approval Notice New Application

31-May-2012
BAUM, Jan-hendrik

Protocol #: DESC5/2012

Title: Investigating social network analysis as a method to map major constraints in physical asset management strategy execution

Dear Mr Jan-hendrik BAUM,

The **New Application** received on **07-Mar-2012**, was reviewed by Research Ethics Committee: Human Research (Humanities) via Committee Review procedures on **02-Apr-2012** and has been approved. Please note the following information about your approved research protocol:

Protocol Approval Period: **26-Apr-2012 -25-Apr-2013**

Present Committee Members:

Fouche, Magdalena MG
Bitzer, Elias EM
Somhlaba, Ncebazakhe NZ
Engelbrecht, Sidney SF
Van Zyl, Gerhard G
Theron, Carl CC
De Villiers, Mare MRH
Van Wyk, Berte B
Mostert, Paul PJ
Hattingh, Johannes JP
Hansen, Leonard LD

Standard provisions

1. The researcher will remain within the procedures and protocols indicated in the proposal, particularly in terms of any undertakings made in terms of the confidentiality of the information gathered.
2. The research will again be submitted for ethical clearance if there is any substantial departure from the existing proposal.
3. The researcher will remain within the parameters of any applicable national legislation, institutional guidelines and scientific standards relevant to the specific field of research.
4. The researcher will consider and implement the foregoing suggestions to lower the ethical risk associated with the research.

You may commence with your research with strict adherence to the abovementioned provisions and stipulations.

Please remember to use your **protocol number (DESC5/2012)** on any documents or correspondence with the REC concerning your research protocol.

Please note that the REC has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

After Ethical Review:

Please note that a progress report should be submitted to the Committee before the approval period has expired if a continuation is required. The Committee will then consider the continuation of the project for a further year (if necessary). Annually a number of projects may be selected randomly for an external audit.

National Health Research Ethics Committee (NHREC) number REC-050411-032.

This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes 2004 (Department of Health).

Provincial and City of Cape Town Approval

Please note that for research at a primary or secondary healthcare facility permission must be obtained from the relevant authorities (Western Cape Department of Health and/or City Health) to conduct the research as stated in the protocol. Contact persons are Ms Claudette Abrahams at Western Cape Department of Health (healthres@pgwc.gov.za Tel: +27 21 483 9907) and Dr Helene Visser at City Health (Helene.Visser@capetown.gov.za Tel: +27 21 400 3981). Research that will be conducted at any tertiary academic institution requires approval from the relevant parties. For approvals from the Western Cape Education Department, contact Dr AT Wyngaard (awyngaar@pgwc.gov.za, Tel: 0214769272, Fax: 0865902282, <http://wced.wcape.gov.za>).

Institutional permission from academic institutions for students, staff & alumni. This institutional permission should be obtained before submitting an application for ethics clearance to the REC.

Please note that informed consent from participants can only be obtained after ethics approval has been granted. It is your responsibility as researcher to keep signed informed consent forms for inspection for the duration of the research.

We wish you the best as you conduct your research.

If you have any questions or need further help, please contact the REC office at 0218089183.

Included Documents:

DESC checklist
Consent form

Sincerely,

Sidney Engelbrecht
REC Coordinator
Research Ethics Committee: Human Research (Humanities)

Appendix E

Questionnaire for Network Data Collection

See next page.



Survey for Social Network Analysis at ***

Participant Details

Name and Surname:

Job Position:

Participant Information


Research Purpose: *The purpose of the thesis is to investigate social network analysis as a tool to map major constraints in physical asset management strategy execution. The purpose of this research is to elucidate informal networks at ***. Therefore data on informal relationships between people is collected and analysed.*

Researcher Details: Jan-Hendrik Baum
 Postgraduate Student (MSc Eng)
 Stellenbosch University
 Phone. +27 744 50 42 74 Mail. 16825853@sun.ac.za


Supervisor Details: Dr. P.J. Vlok
 PhD (Indust Eng), M.Eng. (Mech)
 Stellenbosch University
 Mail. pjvlok@sun.ac.za

- I have read and understood the participant information describing the purpose of the research project and agree to take part.
- I understand the nature of my involvement in it.
- I understand that I may withdraw from the research project at any stage and that this will not affect my status within the project, either now or in the future.
- I understand that while information gained during the study may be published, I will not be identified and my personal results will remain confidential.
- I understand that data will be held confidentially, in a secure place and in a password-protected computer in the form of hard and electronic copies. These data will be accessible to the researcher only.
- I understand that I may contact the research director if I require further information about the research, or if I wish to make a complaint.

Instructions

 **The survey involves 4 question sets regarding your relationships to your colleagues in information exchange and decision making.**


You may answer the questions by identifying colleagues from the provided lists. The lists provide X persons that are arranged in alphabetic order by their first names.

 **Do you want to name people who are not on the provided lists?**


At the end of each question set you find space to add additional persons. To ensure a correct identification, please provide the first name(s), surname and job position of everyone you name.

 **How to answer the questionnaire?**

For each person on the list: First answer SECTION A, then SECTION B.

 **Please mark only *one* box in SECTION B for each person**

Mark boxes with or . If you intend to change your selection fill the selection you want to cancel.

 **Please note the time you are stating to fill in the survey**

..... hh:mm

Signature:

Date:YYYY/MM/DD

Place:

Question Set 1

| SECTION A | | SECTION B | | | |
|--|-------------------------------------|---|-------------------------------------|--------------------------|--------------------------|
| Who do you typically receive work related information from? (At least on a monthly basis) | | How often do you typically receive work related information from this person? | | | |
| | | Hourly | Daily | Weekly | Monthly |
| 0 Example | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 1 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 2 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 3 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| ... | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

Question Set 2

| SECTION A | | SECTION B | | | |
|---|-------------------------------------|--|-------------------------------------|--------------------------|--------------------------|
| Who do you typically receive physical asset management related information from? (At least on a monthly basis) | | How often do you typically receive physical asset management related information from this person? | | | |
| | | Hourly | Daily | Weekly | Monthly |
| 0 Example | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 1 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 2 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 3 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| ... | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

Question Set 3


| SECTION A | SECTION B | | | |
|---|--|-------------------------------------|--------------------------|--------------------------|
| Who do you typically rely on for advice prior to making decision? (At least monthly) | How often do you typically approach this person regarding advice in decision making? | | | |
| | Hourly | Daily | Weekly | Monthly |
| 0 Example <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 1 <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 2 <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 3 <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| ... <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

Question Set 4

| SECTION A | SECTION B | | | |
|--|--|-------------------------------------|--------------------------|--------------------------|
| Who do you typically rely on for approval prior to making decisions? (At least monthly) | How often do you typically approach this person regarding approval in decision making? | | | |
| | Hourly | Daily | Weekly | Monthly |
| 0 Example <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 1 <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 2 <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 3 <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| ... <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

Question Set 5

| | |
|--------------------|-------------------------------------|
| SECTION A | |
| Whom do you trust? | |
| 0 Example | <input checked="" type="checkbox"/> |
| 1 | <input type="checkbox"/> |
| 2 | <input type="checkbox"/> |
| 3 | <input type="checkbox"/> |
| ... | <input type="checkbox"/> |

 Please note the time you finished filling in the survey

..... hh:mm

Thank You !

for your time and energy in participating in this survey

Appendix F

Summary of Results from Case Study A

Table F.1: Results no. 1 - no. 4.

| <i>No.</i> | <i>Result(s)</i> | <i>Implication(s)</i> |
|------------|---|---|
| 1. | Generally high Δ and Δ^V across \mathcal{X}_7 | Beneficial for information exchange but may slow decision processes. Possibly driven by many youthful employees, young age of the operation and performance pressure. No organisational silos are apparent. Apart from that the numerous problem areas on the plant (see other findings) may contribute to the high cohesion. |
| 2. | C_D in $\mathcal{X}_3 > C_D$ in $\mathcal{X}_2 > C_D$ in \mathcal{X}_1 ; C_B in $\mathcal{X}_3 > C_B$ in $\mathcal{X}_2 > C_B$ in \mathcal{X}_1 | Decision making networks achieve a higher degree centralisation. That is, decision making relies on fewer but more central individuals than seen for the information exchange network. |
| 3. | Numerous citations of a37 and a44 in \mathcal{X}_1 and \mathcal{X}_4 | Actors a37 and a44 are production shift leaders that are off-duty. The network structure suggests that there is a demand for information and advice from a37 and a44 that could not be compensated, yet. Additionally, structural holes could loom large. |
| 4. | Actors a5 and a52 are critical cut-vertices in $A - \mathcal{X}_1$ | Actors a5 and a52 are the sole link in information exchange to many contractors, they are important mediators that just as well can become bottlenecks in information flow. Especially in the case of actor a5 this is critical because the actor is the exclusive gatekeeper to about 58 individuals that facilitate engineering tasks that are fundamental to the operation. Albeit, outsourcing of core engineering competencies is critical and may not be sustainable. |

Table F.2: Results no. 5 - no. 12.

| <i>No.</i> | <i>Result(s)</i> | <i>Implication(s)</i> |
|------------|---|---|
| 5. | Peripheral informal position of key competencies | The SNA draws the attention to the fact that key engineering competencies are largely outsourced. This raises questions of how competencies are sustained. |
| 6. | Actor a13 is highly central and prestigious across \mathcal{X}_r ; Cut-vertex to other departments in $A - \mathcal{X}_1$ | The actor is an important cross-functional intermediate and hub for information exchange. Apart from this, a13 achieves the highest indegree for advice and approval in decision making. Further, the actor is an important liaison to other organisational departments. The actor may be an important pivot in information exchange but can become a bottleneck in decision processes. |
| 7. | Actor a26 and a30 are highly central across \mathcal{X}_r | The centrality of the actors may have two fold implications. The actors may be important corner posts for the dispersion of resources in informal networks but already carry a substantial burden due to their high activity in informal networks. |
| 8. | Actor a26 resembles the informal position of a section engineering | Actor a26 may partly compensate the vacant position of a section engineer. This implies a double burden on the actor and may blur responsibilities within the department. It is doubtful that a26 can perform effectively two roles simultaneously. The actor may already be overloaded and become a bottleneck in information exchange and decision processes in future projects. |
| 9. | Low $d_I(a31)$ and $d_I(a50)$ in \mathcal{X}_r | The analysis shows that the actors a31 and a50 are secluded in informal networks and not as integrated as peers are. Supposedly, the actors are substitutes for a37 and a44. They may be still adapting to new roles. |
| 10. | High $d_O(a50)$ across \mathcal{X}_r | Actor a50 indicates for every relation that interactions to almost every single network member are maintained. Informal networks suggest particular unclarity of business or decision processes to actor a50. The actor may presently not be effective in the role he or she occupies and requires dedicated assistance. |
| 11. | High $d_O(a25)$ in \mathcal{X}_1 | The actor a25 maintains a great diversity of information exchange ties across functional areas. It is questionable what drives the actor's particular demand for cross-functional information. |
| 12. | High $d_O(a45)$ in \mathcal{X}_5 | Actor a45 is particular dependent in decision approval. Decisions that pass a45 might therefore be slowed down. There may be value in assessing the allocation of decision rights and processes that involve actor a45. |

Table F.3: Results no. 13 - no. 19.

| <i>No.</i> | <i>Result(s)</i> | <i>Implication(s)</i> |
|------------|---|---|
| 13. | High $d_O(a51)$ in \mathcal{X}_4 | Actor a51 is highly dependent on the advice from the engineering department in making decisions. It may be valuable to understand what drives the actors particular reliance in advice for making decisions. Possibly this actor's activity results from the vacant position of the section engineer for process section two. |
| 14. | Low $d_O(a41)$ and $C'_C(a41)$ in \mathcal{X}_1 | The manager a41 is least active in obtaining information. Inactivity in information exchange may impose problems to the decision base of this manager. |
| 15. | Low connectivity of a14 and a48 and additional structural similarity | The actors a14 and a48 appear consistently less active in networks than other employees. Additionally, the positional analysis points towards the structural similarity of the two actors. The analysis may points towards an inactive or even dysfunctional maintenance planning at the operation. |
| 16. | Network $A - \mathcal{X}_5$ contains a strong component with cyclic sub networks | Within the strong component considerable redundancies in decision approval are present. There are four cyclic sub networks in which decision approval is reciprocated between individuals. Clarifying or reallocating decision rights in this component has the potential to increase the dynamism in decision making. |
| 17. | Network $A - \mathcal{X}_1$ has overly dense interdepartmental blocks | Based on binary numeration, the information exchange interaction between departments outreaches the target value of typically 10% - 30% and is overly connected. The high density may partly be attributable to the small size of blocks and finding no. 1. |
| 18. | High $\Delta_{\mathcal{B}_2 \rightarrow \mathcal{B}_2}^V$ in \mathcal{X}_1 and highest $P_{\mathcal{B}_2 \rightarrow \mathcal{B}_2}$ across \mathcal{X}_r | It is unclear what drives the engineering department to such close internal collaboration. The connectivity may be problem driven. Furthermore, decision making may be inefficient within the engineering class. |
| 19. | Low $\Delta_{\mathcal{B}_4 \rightarrow \mathcal{B}_2}^V$ and $\Delta_{\mathcal{B}_2 \rightarrow \mathcal{B}_4}^V$; low $p_{\mathcal{B}_4 \rightarrow \mathcal{B}_2}$ and $P_{\mathcal{B}_4 \rightarrow \mathcal{B}_2}$ in \mathcal{X}_1 ; Low $\Delta_{\mathcal{B}_2 \rightarrow \mathcal{B}_4}^V$ and $P_{\mathcal{B}_2 \rightarrow \mathcal{B}_4}$ in \mathcal{X}_4 ; low $\Delta_{\mathcal{B}_2 \rightarrow \mathcal{B}_4}^V$ and $\Delta_{\mathcal{B}_4 \rightarrow \mathcal{B}_2}^V$ in \mathcal{X}_5 | The mutual information exchange between the technical and engineering department appears to be the weakest relationship between departments. Engineering obtains sparse advice from technical department. |

Table F.4: Results no. 20 - no. 24.

| <i>No.</i> | <i>Results(s)</i> | <i>Implication(s)</i> |
|------------|---|---|
| 20. | Low $\Delta_{\mathcal{B}_3 \rightarrow \mathcal{B}_1}^V$, $p_{\mathcal{B}_3 \rightarrow \mathcal{B}_1}$ and $P_{\mathcal{B}_3 \rightarrow \mathcal{B}_1}$ in \mathcal{X}_1 | In comparison to other classes, the management class provides least information to production. |
| 21. | Low $\Delta_{\mathcal{B}_1 \rightarrow \mathcal{B}_2}^V$, $\Delta_{\mathcal{B}_1 \rightarrow \mathcal{B}_3}^V$, $p_{\mathcal{B}_1 \rightarrow \mathcal{B}_2}$, $p_{\mathcal{B}_1 \rightarrow \mathcal{B}_3}$ in \mathcal{X}_4 , $P_{\mathcal{B}_1 \rightarrow \mathcal{B}_2}$, $P_{\mathcal{B}_1 \rightarrow \mathcal{B}_3}$ in \mathcal{X}_4 | Little advice reaches the management class from engineering and production. The decision base of management may become a problem if it is disconnected from the realities at the fundament of the operation. It may be questioned if management decisions are made based on incomplete information. |
| 22. | High density in the form of $\Delta_{\mathcal{B}_k \rightarrow \mathcal{B}_1}^V$ | The network depicts a tendency of individuals to push off decisions up the hierarchy. |
| 23. | $P_{\mathcal{B}_2 \rightarrow \mathcal{B}_2} = 23.84\%$ | Almost a quarter of all decision approval processes are taking place within the engineering class. There may be value in assessing the allocation of decision rights and possible redundancies in processes. |
| 24. | e_i and $x^{(n)}$ unreasonable | Production supervisor achieve highest authority weights. It is believed that the the eigenvector centrality is flawed due to unreasonably high $d_O(a25)$ and $d_O(a50)$. |

Appendix G

Summary of Result Validation from Case Study A

Table G.1: Validation of results no. 1 - no. 6.

| <i>No.</i> | <i>Comment(s)</i> | <i>Condition</i> |
|------------|---|------------------|
| 1. | Lately, two experienced and central actors left the plant. This significantly increased cohesion and self alliance among employees. | TRUE |
| 2. | Not applicable. | |
| 3. | Shift leaders left the plant two and five months ago. Citations are caused by SNA's bias towards long term relationships. | TRUE |
| 4. | SNA approximates the reporting structure. The plant is not aware of potential short comings. Though, it is acknowledged that actor a5 is accomplishing a difficult role in managing as many contractors. | TRUE |
| 5. | When the operation was commissioned the engineering labour was under resourced based on unreasonable assumptions. Maintenance activities could not be facilitated adequately. Therefore it was decided to incorporate the assistance of contractors. The plant is aware of the risk and aims to increase engineering staff and terminate outsourced activities. | TRUE |
| 6. | The network resembles the organisational structure. It is the case that subordinates do not take full responsibility of their duties and elevate decisions to actor a13, this results in an increases the "unnecessary" workload on a13. The plant's systems are problematic. Therefore the respective departments significantly draw on confirmation from the plant manager. | TRUE |

Table G.2: Validation of results no. 7 - no. 18.

| <i>No.</i> | <i>Comment(s)</i> | <i>Condition</i> |
|------------|--|------------------|
| 7. | The actors involvement is not reasonable. Actor a26 is committed to resolve numerous production process problems that boosts his connectivity. Because it was recognised that the actor was overloaded, responsibilities were reallocated to relieve this actor. The huge involvement of actor a30 is mainly attributable to the vacant position of a second section engineer. The legal responsibilities of an engineer necessitates the engineer's involvement and significantly overload this position. Additionally, see no. 18. The engineer is running out of capacity for additional improvement initiatives due to the high workload from the ordinary day to day activities. Recently, the plant is facing restructuring measures that intend to relieve both actors. | TRUE |
| 8. | The actor was fulfilling the role of an engineer for the dry section at the time of the survey. Recently, the plant is facing restructuring measures that also intend to relieve this actor. Responsibilities have been reallocated to actor a34. | TRUE |
| 9. | The actors are the substitutes to actors a37 and a44. They are still in the process of adapting their new roles. | TRUE |
| 10. | Sensitive subject. No validation has been obtained. | |
| 11. | Sensitive subject. No validation has been obtained. | |
| 12. | The instrumentation services provide dedicated support for the technical department. They jointly take decision regarding control and instrumentation systems. Changes involve a so called "Plant Change Notification" process. | TRUE |
| 13. | There are a lot of mechanical problems at the process section 2. In order to resolve problems the a51 is in constant communication with engineering. | TRUE |
| 14. | Sensitive subject. No validation has been obtained. | |
| 15. | Problems regarding the maintenance function could be confirmed. Currently, the function can not effectively assist the engineering department. | TRUE |
| 16. | There is room for improvement by stream lining decision making. Additionally the compliance to existing processes is improvable. | TRUE |
| 17. | See no. 1. | TRUE |
| 18. | The engineering department is assigned by other departments to facilitate tasks that fall out of the engineering department's responsibility this boosts the cohesion within the department and decision approvals draw on the section engineer a30. The maintenance function is dysfunctional what demands the strong involvement of foremen. | TRUE |

Table G.3: Validation of results no. 19 - no. 24.

| <i>No.</i> | <i>Comment(s)</i> | <i>Condition</i> |
|------------|---|------------------|
| 19. | The collaboration between departments is lacking and the problem is a traditional feud. Though, it is recognised that the departments' communication is vital and that collaboration has to be improved. The issue has been and is being addresses. The relationship could already be improved. | TRUE |
| 20. | The communication is adequate. | FALSE |
| 21. | The validation does not deliver conclusive evidence for this statement. The statements by research participants contradict each other. | INCONCLUSIVE |
| 22. | See, no. 6. | TRUE |
| 23. | There is room for improvement. See no. 16. | TRUE |
| 24. | Not applicable. | |

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