

# MAPPING PRIMARY CONSTRAINTS IN PHYSICAL ASSET MANAGEMENT STRATEGY EXECUTION, USING SOCIAL NETWORK ANALYSIS

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## ABSTRACT

The successful execution of a physical asset management strategy is an important value driver for organisations that are highly dependent on the service delivery of physical assets. Research demonstrates that strategic targets are often not met, and that the means to detect the constraints that can undermine strategy execution efforts are deficient. The purpose of this article is to investigate social network analysis (SNA) as a method to map primary constraints in physical asset management strategy execution (PAMSE). As an interim result, the study found that dysfunctional information flow and poor decision-making are the primary constraints that can hinder the PAMSE. An SNA application methodology was developed and applied at two research sites in the South African mining industry. This study found that SNA can be used to map constraints experienced in PAMSE; but it also points towards important prerequisites that have to be established for SNA to be successful.

## OPSOMMING

Die suksesvolle uitvoering van die fisiese batebestuurstrategie is 'n belangrike genereerder van waarde vir organisasies wat 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 artikel 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. 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, en dan op twee teiken-aanlegte in die Suid-Afrikaanse mynboubedryf toegepas. 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.

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## 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 way to generate revenue. Heavy industries in particular rely on a built infrastructure as the principal means for operation and service delivery. Today's increased tempo, intensity, and volatility of operations demand the scrupulous compliance of physical assets to the defined service targets. Consequently, the effective management of physical assets becomes an important driver for profitability and business success. The purpose of physical asset management (PAM) boils down to supporting the organisational strategic plan by ensuring service delivery and the most effective use of physical assets. Woodhouse [26] 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.* [1] 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 [27], organisations realised that by working through functional silos, major opportunities were missed. Since coming to this realisation, the argument for an interdisciplinary approach to PAM - to ensure that an appropriate mix of skills is 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. Tsang [24], in particular, points to human dimensions as a key issue for the successful management of physical assets. Woodhouse [27] suggests that PAM is achieved through tools and techniques as well as through restructuring and performance measures; but that it is ultimately the employees who achieve the defined targets. In the words of the PAM veteran, John S. Mitchell [18]:

*"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 boundaries and myopia of organisations. The contemporary perspective on PAM highlights a multidisciplinary skill set and cross-functionality, and targets organisational synergies. The prevalent threats - traditional paradigms, a silo mentality, and communication deficits - have shifted towards an integrated view that especially emphasises the strategic and human dimension. This fairly new approach has been shared among researchers and practitioners alike, and has matured with the publication of the Public Available Specification 55 (PAS 55) - a guiding framework for PAM published by the British Standards Institution (BSi) (see BSi [2] and BSi [3]). PAS 55 joins the international consensus on PAM, and is the primary contributor to the emerging ISO 55000 standard. PAS 55 can be seen as the blueprint for the contemporary interpretation of PAM.

## 2. SUCCESS ORIGINATES IN GOOD EXECUTION

The PAS 55 standard proposes an asset management system (AMS) that provides the 'line of sight' between organisational strategic direction and everyday management of physical 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 such a framework is vital to master the complexity and diversity of assets in relation to the organisational objectives. As with the generic strategic management process, the AMS comprises a physical asset management strategy planning, implementation, and review phase (compare Robbins & Coulter [21] and BSi [2]). At the heart of the AMS lies a physical asset management strategy (PAMS) that is derived from the organisational strategic plan and policies. The PAMS is an approach to the management of physical assets that is directed towards achieving organisational target(s). This approach involves innumerable employees, processes, and physical assets that, when connected, evolve into action that leads to tangible outcomes and the attainment of strategic targets. For our purposes we defined physical asset management strategy execution (PAMSE) as the process of translating the

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

We believe that there is an enormous gap in the body of knowledge about PAM. So far, both the literature and frameworks such as PAS 55 have focused mainly on devising strategies, while the properties of strategy execution are disregarded. Not much research has been concerned with influences that affect the process of materialising the PAMS. Instead, publications in PAM often focus on asset life cycle activities and on advancing new methodologies for planning, assessment, and optimisation purposes (see, for example Hastings [10] and Amadi-Echendu *et al.* [1]). Research has shown that good execution is indispensable to strategy success. Kaplan & Norton [13] points out that highly productive organisations typically place more emphasis on executing strategy than formulating it. Neilson *et al.* [20] and Robbins & Coulter [21] agree that only the ability to deliver the intention of a strategy sustains an advantageous position. Multiple studies document the failure of this ambition. Kaplan & Norton [14] highlight that 60 to 80 per cent of all companies fall short of the strategic targets that they have set. Zook & Allen [27] find that 90 per cent of all companies fail to realise their strategic ambitions. Moreover, Mankins & Steele [16] find that on average only 63% of strategies' financial performance is realised. The lack of success in executing strategy is daunting. Strategy execution failure seems to be a common dilemma, and the strategy execution process appears to be prone to failure.

The crux of the matter is that a brilliant strategy is meaningless if its intentions cannot be delivered. The field of PAM appears to be dominated by strategic planning and technical management, focusing on system optimisation and defect elimination. However, the link between strategic ambitions and asset life cycle measures is largely missing. Following Higgins [12], the cross-functional character of PAM further complicates the dissemination and integration of execution actions. It appears that PAM falls short of addressing the properties of strategy execution, thus ignoring a salient reason for the failure to succeed.

Publications of management research do, however, clarify a number of constraints that can stifle the strategy execution process. The studies by Mankins & Steele [16] and Neilson *et al.* [20] deepen insight into the 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.

The work by Neilson *et al.* [20] may provide the most extensive and exhaustive research in the field. According to them, the research involves more than 125,000 data profiles representing more than 1,000 companies, government agencies, and non-profit organisations in more than 50 countries. They identified four 'building blocks' that most influence strategy execution. These are shown in Figure 1.

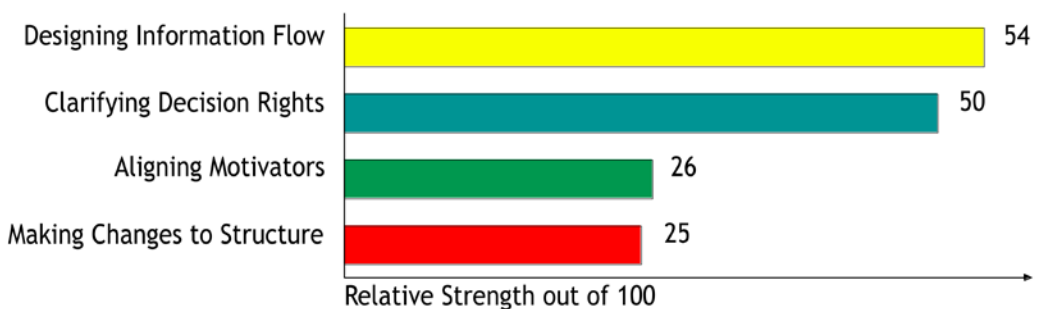


Figure 1: Building blocks of successful strategy execution adapted from Neilson *et al* [20]

The authors make it clear that organisations habitually initiate restructuring measures immediately in efforts to improve execution performance; but they find that structural measures are least effective in the long term. The reasons for improved strategy execution are to be found elsewhere. Their research suggests that actions about decision rights and flow of information are far more promising. In fact, they are about twice as effective as improvements made by the other two building blocks. Not attending to these factors may put insurmountable obstacles in the way of the strategy execution process. Moreover, the presence of similar problems is consistently echoed by texts in PAM and by the experience of practitioners. However, PAM continues to pay poor attention to the factors that may constrain its success. The interplay of the factors above leads to an area of opportunity composed of four main arguments, shown below:

- PAMSE is imperative for success
- PAMSE cuts across functions
- Primary constraints to PAMSE are likely to be found in the spheres of information flow and decision-making
- Within PAM, an especially strong focus on the human dimension emerges

When brought together, these factors significantly complicate efforts to improve an organisation's ability to execute strategy. Because PAM involves a multifaceted field of responsibility that transcends organisational boundaries, the task of unravelling the information flow and the decision-making within the organisation seems insoluble. Strategic PAM initiatives may require individuals and processes to change and adapt in some or other way. Mitchell [17] emphasises that organisational conflict in change processes surrounding PAM is typically more pervasive and difficult to solve than technical issues. Correspondingly, Amadi-Echendu *et al.* [1] expect major PAM challenges to be most likely to arise from the human dimension, in organisational settings and knowledge transfer.

### 3. MAPPING CONSTRAINTS WITHIN THE INFORMAL ORGANISATION

PAMSE is complex; but an improved ability to execute 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, we draw on the findings about problems in strategy execution from the management literature outlined above, and project them into the field of PAM. Knowing potential constraints in the execution process is only one of the challenges. An inability to keep track of the constraints inside the organisation significantly hampers effective action in overcoming these constraints. The resources of an organisation are limited, and reference points are required to direct action to where they can be most effective. The question is whether there is a method that can detect the primary constraints in PAMSE and thus enable management to engage in corrective action. Ideally, the mode of analysis captures problems in cross-functional organisational settings, has a particular focus on the human dimension, and is capable of analysing information flow and decision-making. These requirements give rise to social network analysis (SNA) as a possible way of mapping the problems in PAMSE.

SNA may be best introduced by a simple example. Consider a fictitious open cast mining operation with an assortment of employees. Regardless of each individual's occupation, the employees may be connected by diverse relationships: some may be good friends, while others may be members of the same sports club. Yet it can be decided to focus on one specific relationship that connects two individuals. 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 emerges that describes the information exchange at the mine. In short, a social network is a collection of social entities (people) and the information on the relationships (information exchange) between them.

SNA is a research paradigm and a collection of methods used to analyse the structure of social networks. The primary tenet of SNA is that a network's structure influences the

actions of its members. Based on this assumption, SNA may produce insight into how a network influences information flows and decision-making inside an organisation. SNA is not attached to an organisation's formal structure or processes; it disregards hierarchical relationships and breaks through formally-defined working structures. Instead, SNA focuses on the so called 'informal organisation': the empirically-determined relationships between people as opposed to relationships that are implied by the formal organisational structure. Thus SNA reflects the actual working dynamics between people.

This leads to the second reason for using SNA. While the human dimension is repeatedly highlighted both as a key factor for success and as an immense challenge, the methods of SNA have been proven to reflect adequately on its dynamics. Furthermore, publications indicate that SNA is capable of grasping problems in the domains of strategic alignment, information exchange, decision-making, and organisational change (Krackhardt & Hanson [15], Haythornthwaite [11], Cross *et al.* [7], Colella [6], Cross *et al.* [8], and Cross *et al.* [9]).

The concepts of SNA have been around for a long time, but according to Carrington *et al.* [4], it was only in the 1990s that the interest in 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 vastly different fields. Chinowsky *et al.* [5] demonstrate that the method has also received attention within the engineering and project management fields. However, as Cross *et al.* [7] argue, while it has been demonstrated that informal networks pervade and affect life and work within organisations, how to assess and support informal networks often remains a mystery to practitioners, mostly because of the technical nature of the publications and the network terminology that is used. 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. Adopting a network perspective to analyse the primary constraints in PAMSE is potentially such an opportunity.

#### 4. INTERIM RESULT

The role of PAMSE is vital to the success of PAM, and the identification of constraints can provide the basis for corrective action. SNA attends to the traits of the PAM field, and is clearly able to address problem areas that may be primary constraints in PAMSE. For that reason, SNA may be adequate in unveiling constraints in PAMSE.

A beneficial application of SNA in PAM may ultimately yield a novel way to support a more effective deployment of the PAMS. We therefore investigated SNA as a method to map primary constraints in PAMSE.

#### 5. METHODOLOGY

Before engaging in an SNA, we reflected on 'information flow' and 'decision-making' as problem areas in PAM. Dialogue with experienced practitioners confirmed that these were problem areas in PAM. In the next step we developed an SNA application methodology that focuses on the identified problem areas. The methodology was derived from leading texts in SNA, such as the works by Wasserman & Faust [25], Scott [22], Carrington *et al.* [4], and Scott & Carrington [23]. An abridged step sequence of the application methodology is provided in Table 1. Network data for the study was collected by surveys conducted in June and July 2012. The details of the developed methodology rely on numerous concepts of SNA and its distinct terminology. In order to avoid confusing readers who are inexperienced in SNA, we have not presented the methodology in great detail.

Once we were equipped to explore the informal networks of information flows and decision-making, we used the developed methodology, applied it at two suitable research sites, and tested the ability of SNA to map primary constraints in PAMSE. The SNA applications yielded a number of results; but they also encountered barriers.

**Table 1: Abridged SNA application methodology**

<b>I. Preliminaries</b>	
a) Field of application	Organisations that significantly rely on the performance of physical assets.
b) Unit of observation	Individuals involved in PAM.
<b>II. SNA design and boundary</b>	
a) SNA study design	Whole and one-mode network approach.
b) Network boundaries	Hybrid of normalist and realist perspective.
<b>III. Constructing networks</b>	
a) Information flow (1)	Network of work-related information exchange.
b) Decision-making (2)	Network of advice in decision-making and network of approval in decision-making.
<b>IV. Collecting data</b>	
a) Actor identification	Creation of a fixed-list of the relevant actor set on the basis of study boundary, organisational records, and consultation of managers.
b) Data collection technique	Collection of social network data using an expanding selection survey method.
c) Questionnaire design	Survey questions are in the form of: "Who do you typically receive work related information from?" and "How often do you receive work related information from this person?"
d) Human subject protection	Conduct of survey research is considered. Anonymity of individuals is protected.
<b>V. Analysing networks</b>	
a) Visual inspection	
b) Cohesive subgroups	
c) Centrality and centralization	
d) Positional analysis	
e) Blockmodeling	
<b>VI. Validation of results</b>	
Revisit the research site and conduct interviews about the obtained results.	

## 6. RESULTS FROM SNA APPLICATIONS

The SNA application was facilitated in cooperation with two mining operations in South Africa. For convenience, and to maintain confidentiality, the two case studies are referred to as case study A and B. We begin by highlighting some of the practical examples of potential setbacks to employing SNA.

### 6.1 Case study A

Although the organisation in case study A intended to cooperate in an SNA, the approval process for the analysis failed, mainly because no one took responsibility for formally approving or declining the SNA application proposal: it was passed between individuals, and the approval process lost momentum and stalled. As a last resort, the research request was taken to the organisation's executive management. After sponsorship had been obtained from a senior manager, the study process was revived. The next hurdle in the application process was to obtain records that reflected the current organisational structure, on which the survey collecting network data at the research site would need to draw significantly to identify network members. In several cases these records were out dated, delaying the issuing of questionnaires. The SNA study was promoted by management by informing the staff about the study and asking for participation. Four weeks after the questionnaires had

been handed out a response rate of only 27.6 per cent had been achieved. This was despite senior management informing participants about the study, asking for their participation, and issuing an additional 'reminder' to every non-respondent. Owing to the non-responsiveness of the study participants it was decided to discontinue the study.

Although the SNA in case study A failed, a number of considerations and results emerge that can be taken into account.

Müller-Prothmann [19] highlights that it is essential to create motivation among employees by building an understanding of the analysis and the benefits of participation. He also highlights the important role of managers as promoters for the SNA within the organisation. These factors were confirmed as fundamental determinants for the success of an SNA application. The study approval process in case study A shows that implementing an SNA demands the cooperation of an individual with the authority and courage to drive the SNA project. Apart from this, the study process and its benefits have to be carefully coordinated with the responsible management of each functional unit. Presumably survey participants are best informed and motivated by the active personal involvement of the researcher. However, with a growing actor population and geographically distant research sites, this process becomes very resource-intensive. In case study A, educating the research participants could only be done via email. This may have been insufficient to reach an adequate level of commitment from survey participants, and may have contributed to the failure of the SNA application. Apart from that, case study A experienced problems in the organisational culture. The success of an SNA application may also rely on a participative research environment and open-minded research subjects who willingly engage in the study. If the organisational culture is not supportive, and if employees feel insecure or even threatened when data is collected about them, the SNA application may be at risk. A problematic organisational culture in case study A may have decreased the commitment of research participants even further, causing the data collection to stall.

Case study A shows that, unless management and research participants are motivated and actively engaged 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 an SNA. On the basis of the findings from case study A, we believe that energetic senior sponsorship, a supportive organisational culture, and the adequate motivation of employees are important prerequisites for the success of an SNA application. In case study A, these prerequisites were only partly met, presumably leading to the failure of the SNA application. It is noteworthy that the findings from case study A echo concerns stated in Müller-Prothmann [19].

## **6.2 Case study B**

Case study B received considerable support from the research partner, and was conducted in collaboration with the Asset Care Research Group of Stellenbosch University. As a result the survey was administered in person, and the research participants could be educated and motivated. Moreover, the organisation at the research site had a supportive attitude towards the research process. The questionnaire return rate was thus 100 per cent, and a thorough SNA of the plant was conducted. The SNA captured the informal working dynamics at the research site and delivered comprehensive insight into potential constraints in PAMSE. The application yielded 24 findings in total, of which some were expected to have a great impact on future PAM targets. The SNA application in case study B revealed three primary constraints in PAMSE that are based on a combination of different findings: overloaded key actors, collaborative breakdowns, and excessive intra-departmental cohesion. An outline of our findings is presented below.

### **6.2.1 Overloaded key actors**

SNA uses centrality measures to pinpoint individuals in a network whose connectivity elevates them to particular influential positions. Actors in a particular central position have disproportional power to influence other network members. Working through these individuals is essential to the PAMSE. The point is that a central quality is twofold: high connectivity elevates individuals to influential positions; but increasing requests by other

network members risk their becoming overloaded and turning into bottlenecks. Figure 2 shows the scatterplot of indegrees and outdegrees in the information exchange network. Throughout networks and measures, the actor trio of a13, a26, and a30 stands out as particularly central and key to the operation. 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 they can end up choking the effectiveness of the organisation by blocking information flows, slowing decision-making, and eventually constraining the PAMSE.

In addition, Figure 2 reveals an alarming positioning of the maintenance planning function. The planners a14 and a48 appear to be isolated from the plant's information exchange network, suggesting either a lack of integration or a dysfunctional state of this function.

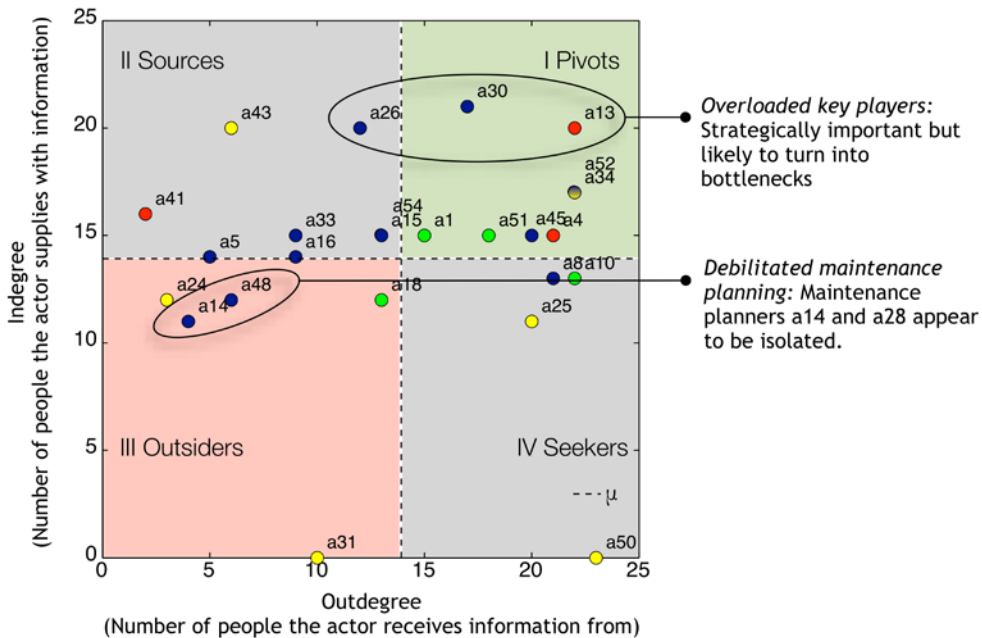


Figure 2: Degree distribution of the information exchange network

Figure 3 shows another example within the decision approval network. This network achieved the highest centralisation of all the networks that were created. That is, decision approval relationships largely rest on a few very central actors in the network. For this network the degree distribution highlights actor a13 as being overly central.

In fact, the SNA suggests that the manager's subordinates shy away from taking responsibility for decision approval themselves, but frequently leave decisions to the manager (a13). This slows decision-making and results in an unreasonable burden on manager a13.

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There is an inherent risk in this structure, because the single channel of information can easily be overstrained and thus obstruct the information flow. The actor may distance himself from the plant’s core network because the sub-network to peripheral engineering contractors drains the actor’s capacity. This results in the loss of the link to staff who facilitate fundamental tasks at the plant, thus establishing a major impediment for PAMSE.

Second, it was found that collaboration between the engineering and technical departments is lacking. The information exchange network’s adjacency matrix has been permuted using departmental classes. Departments are thus treated as aggregated social units that define the position of the actors they contain; these aggregate units are also termed ‘blocks’. The matrix permutation is used to gain understanding of information exchange habits between the different departments, rather than focusing on the individual. Table 2 shows the proportion of realised and possible information exchange relationships between two departments. The measure is called ‘density’.

Table 2: Inter- and intra-departmental information exchange

		Recipient			
		Management	Engineering	Production	Technical
Source	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%	52.06%
	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 departments. It seems that these two departments are most distant in terms of sharing information. Information flows rely on a density of only 13.85 and 17.19 per cent respectively. The functional relationship between the two departments is indispensable for the successful execution of strategic initiatives, because the departments collaboratively facilitate PAM initiatives.

6.2.3 Excessive intra-departmental cohesion

The analysis also points to potential redundancies and inefficiencies within the key function of engineering. First, the engineering department attracts attention because it shows an obviously high internal connectivity throughout different networks. The excessive density within the engineering department could be attributed to the dysfunctional state of the maintenance planning function that forces foremen and engineers into self-reliance and close collaboration. Second, the engineering department makes up a large part of the so-called ‘strong component’ in the decision approval network. This component consists of a space in the network where decision approval processes are reciprocated, and non-compliance with business processes undermines effective work processes.

The combination of these drawbacks results in unclear responsibilities and leads to inadequate collaboration among the employees, impeding the effectiveness of the engineering department

7. REVISITING THE RESEARCH SITE

In order to validate the results of the SNA, they have to be evaluated by the individuals who are the subjects of the analysis. The research site was revisited, and individuals were presented with the analysis results to test their validity. Of the original 24 findings, 19 were found to portray the situation at the plant accurately. In one of the findings, however, no conclusive validation was obtained because the statements made by interviewees were contradictory. In three of the cases, we refrained from validating the findings owing to the sensitivity of the subject.

Overall, an SNA was successfully applied at one research site, identifying a number of constraints to PAMSE. The validation process largely confirmed the presence of these important areas of concern.

## 8. CONCLUSION

In case study A no SNA could be conducted. The experience gained from the research process in case study A suggested four important prerequisites for the success of an SNA application. These are:

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

In case study A these prerequisites were only partially present, which was presumably why the research had to be discontinued. Conversely, the prerequisites were fully present in case study B. Presumably as a result of this, the developed SNA application methodology was executed successfully and no drawbacks were experienced during the research process. In case study B, the SNA discerned a number of factors that could threaten the successful execution of the PAMS. Most importantly, the SNA mapped three primary constraints in PAMSE, which were confirmed by the validation process. These are:

- Overloaded key actors
- Collaborative breakdowns
- Excessive intra-departmental cohesion

It is concluded that SNA can be used as a method to map primary constraints in PAMSE. However, important prerequisites have to be established to reach the successful application of SNA.

The next logical step to take following this study of SNA is to develop plans to improve the informal networks in case study B. On the basis of our results, the plant management could take corrective action to resolve the highlighted constraints. After improvement plans have been implemented and an adequate period of time has elapsed, a second SNA could be conducted. It is important to remember 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 whether the defects identified in the plant's networks can be eliminated.

## REFERENCES

- [1] Amadi Echendu, J.E., Brown, K., Willett, R. & Methew, J. 2010. *Definitions, concepts and scope of engineering asset management*, Springer Verlag.
- [2] BSi 2008. *Public Available Specification 55 Part 1: Specification for the optimized management of physical assets*, The Institute of Asset Management.
- [3] BSi 2008. *Public Available Specification 55 Part 2: Guidelines for the application of PAS 55-1*, The Institute of Asset Management.
- [4] Carrington, P.J., Scott, J. & Wasserman, S. 2005. *Models and methods in social network analysis*, Cambridge University Press.
- [5] Chinowsky, P.S., Diekmann, J. & O'Brien, J. 2010. Project organizations as social networks, *Journal of Construction Engineering and Management*, 136(4), pp 452-458.
- [6] Corella, B. 2010. A workshop for aligning networks with strategy. In *The organisational network fieldbook: Best practices, techniques and exercises to drive organisational innovation and performance*, Jossey-Bass.
- [7] Cross, R., Borgatti, S. & Parker, A. 2002. Making invisible work visible: Using social network analysis to support strategic collaboration, *California Management Review*, 44(2), pp 25-47.
- [8] Cross, R., Singer, J., Corella, S., Thomas, R.J. & Silverstone, Y. 2010. *The organisational network fieldbook: Best practices, techniques and exercises to drive organisational innovation and performance*, Jossey-Bass.

- [9] Cross, R., Thomas, R.J., Dutra, A. & Newberry, C. 2010. Positioning a new leader for success through network fine-tuning. In *The organisational network fieldbook: Best practices, techniques and exercises to drive organisational innovation and performance*, Jossey-Bass.
- [10] Hastings, N.A.J. 2009. *Physical asset management*, Springer-Verlag.
- [11] Haythornthwaite, C. 1996. An approach and technique for the study of information exchange, *Library & Information Science Research*, 18(4), pp 323-342.
- [12] Higgins, J.M. 2005. The eight 's's of successful strategy execution, *Journal of Change Management*, 5(1), pp 3-13.
- [13] Kaplan, R.S. & Norton, D.P. 2001. *The strategy focused organization: How balanced score-card companies thrive in the new business environment*, Harvard Business School Press.
- [14] Kaplan, R.S. & Norton, D.P. 2008. *The execution premium: Linking strategy to operations for competitive advantage*, Harvard Business School Press.
- [15] Krackhardt, D. & Hanson, J.R. 1993. Informal networks: The company behind the chart, *Harvard Business Review*, 71(4), pp 104-111.
- [16] Mankins, M.C. & Steele, R. 2005. Turning great strategy into great performance, *Harvard Business Review*, 83(7), pp 65-72.
- [17] Mitchell, J.S. 2007. *Physical asset management handbook*, Clarion Technical Publishing.
- [18] Mitchell, J.S. 2012. Physical asset management course, presented at Stellenbosch University in June 2012.
- [19] Müller-Prothmann, T. 2006. *Leveraging knowledge communication for innovation: Framework, methods and applications of social network analysis in research and development*, PhD thesis, Peter Lang Verlag.
- [20] Neilson, G.L., Martin, K.L. & Powers, E. 2008. The secrets to successful strategy execution, *Harvard Business Review*, 86(6), pp 60-70.
- [21] Robbins, S.P. & Coulter, M. 2012. *Management*, Prentice Hall.
- [22] Scott, J. 2000. *Social network analysis: A handbook*, Sage Publications.
- [23] Scott J. & Carrington, P. 2011. *The SAGE handbook of social network analysis*, Sage Publications.
- [24] Tsang, A.H.C. 2002. Strategic dimensions of maintenance management, *Journal of Quality in Maintenance Engineering*, 8(1), pp 7-39.
- [25] Wasserman, S. & Faust, K. 1994. *Social network analysis: Methods and applications*, Cambridge University Press.
- [26] Woodhouse, J. 2006. *Putting the total jigsaw puzzle together: PAS 55 standard for the integrated, optimized management of assets*, The Woodhouse Partnership Ltd.
- [27] Zook, C. & Allen, J. 2001. *Profit from the core: Growth strategy in a era of turbulence*, Harvard Business School Press.