Towards an integrative supply chain performance measurement model: A case study of Vivo Energy lubricants

Moses Muputisi

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ABSTRACT

This research presents the use of a Data Envelopment Analysis (DEA) based approach for equitable performance evaluation of supply chain partners in today's increasingly global, complex and extended supply chains. A case study company is analysed to validate the proposed shortcomings of current performance measurement approaches and hence qualify the need for an alternative approach that promotes integration and collaboration. An alternative DEA based supply chain performance measurement approach, which addresses the extended nature of the supply chain, is proposed and demonstrated. Through the case study, DEA is proven to overcome the shortcomings of existing approaches and exhibit most of the attributes of an effective supply chain performance evaluation tool. The proposed method can help supply chain managers make better trade-off and benchmarking decisions across the supply chain as a whole thereby minimizing potential conflicts that emanate from localized decision making.

KEY WORDS: Data Envelopment Analysis, Supply Chain, Performance Measurement

DECLARATION

I, **MOSES MUPUTISI**, declare that this research report is my own work except as indicated in the references and acknowledgements. It is submitted in partial fulfilment of the requirements for the degree of Master of Business Administration in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or any other university.

Signed at ……………………………………………………

On the …………………………….. day of ………………………… 20…..

DEDICATION

To my wife, Cynthia, my boys, Tatenda and Tapiwa and my daughter, Tendai, for all the sacrifices they made and the support they gave.

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CHAPTER 1. INTRODUCTION

1.1 Purpose of the study

The purpose of this research is to determine, through a case study of the Vivo Energy lubricants supply chain, whether existing supply chain performance measurement methods and metrics are sufficient for the integration objectives of supply chain management. The research then presents a Data Envelopment Analysis (DEA) based methodology for integrative performance evaluation of the supply chain as a whole as well as that of its partners. The proposed method promotes integration in the supply chain by quantifying the contributions and shortfalls by all partners towards the performance of the entire supply chain, which helps to show the potential mismatch of priorities and conflict between supply chain partners.

1.2 Context of the study

Organisations all over the world are realising the increasing advantage of competing as part of a supply chain (comprising their suppliers, affiliates and customers) rather than as individual firms (Wu, Chuang, & Hsu, 2014). This is because an increasing proportion of value creation and opportunities for businesses has moved outside the traditional boundaries of the focal firm (Halldorsson, Kotzab, Mikkola, & Skjøtt-Larsen, 2007). Managing and controlling the flow of materials, information and finance across the chain, defined as supply chain management by Wu et al. (2014), has therefore grown into a strategic function and a source of competitive advantage for organisations (Shi & Yu, 2013). Several research studies have proven this by showing empirical evidence linking supply chain performance and the financial performance of the business (Estampe, Lamouri, Paris, & Brahim-Djelloul, 2013; Qrunfleh & Tarafdar, 2014; Shi & Yu, 2013).

The growing significance of supply chain management brings forward a number of implications for both supply chain managers and the businesses at large. The implications mainly relate to integration and collaboration within the supply chain; the role played by the individual partners in the chain, how to collaborate and share resources between the partners, the decision making framework to manage these partners and the performance measurement approach (Halldorsson et al., 2007). Supply chain management requires that firms work closer together, making collaboration and integration between supply chain partners more and more important. Shi and Yu (2013), on the basis of a review of 49 research articles on the link between firm performance and business performance, highlight integration as one four key pillars for competitive supply chain performance. Won Lee, Kwon, and Severance (2007) and Vaidya and Hudnurkar (2013) also confirm collaboration and integration as positive moderating factors between supply chain and business performance.

A comprehensive performance measurement system of any business process is important because it gives feedback on whether the process and its activities meet their desired goals and objectives. It also reflects the gap between actual and target performance, which can also offer a basis for corrective actions and performance improvements (Bhagwat & Sharma, 2007). The same applies to supply chain performance measurement systems; developing a comprehensive and integrated performance measurement system that aims to balance the performance of the individual supply chain partners in order to optimize the performance of the whole chain, is vital in order to support the integrative philosophy behind supply chain management. Such a performance management system is critical as it can also provide evidence to all supply chain partners that indeed value is being created and shared equitably across the chain (Estampe et al., 2013). It also helps minimize the sub-optimization of the supply chain that normally emanates from optimization efforts sorely targeted at localized supply chain partners' processes (Vaidya & Hudnurkar, 2013).

Existing supply chain performance measurement methods however fall short in meeting and supporting the integration philosophy; they are either designed to measure the performance of the individual entities with little regard of the integration complexities of supply chains (Estampe et al., 2013), or are too operational such that they fail to capture the performance against the desired strategic supply chain attributes of integration and collaboration (Shi & Yu, 2013). Halldorsson et al. (2007) and Shi and Yu (2013) partly attribute this lack of comprehensive measurement to insufficient theoretical foundations for the field of supply chain management; arguing that supply chain performance management can benefit from more scientific theories that come from outside its domain, supported by more empirical results and tested under different environmental conditions. Shi and Yu (2013) also note that most supply chain performance related studies have been done focussing on the companies in Europe and the United States of America. They therefore argue for more empirical evidence of similar and other related studies from other parts of the world before findings can be confirmed and generalised.

1.2.1 *Data Envelopment Analysis*

Data Envelopment Analysis (DEA) is one of the performance evaluation methodologies that promise to assist with the supply chain performance evaluation problem (Shafiee, Lotfi, & Saleh, 2014; Xu, Li, & Wu, 2009). DEA is a linear programming based methodology introduced by Charnes, Cooper, and Rhodes (1978) to measure the efficiency of Decision Making Units (DMU). DMUs are homogenous organisational or functional entities that process multiple inputs into multiple outputs. DEA calculates the efficiency of a DMU by comparing its aggregate output to its aggregate input. Through benchmarking of the efficiencies of the DMUs, DEA identifies efficient DMUs that become benchmarks for the inefficient DMUs. This way, DEA allows for collaborative cooperation between DMUs and sharing of best practices to improve the inefficient DMUs (Dyson & Shale, 2010). DEA's relative suitability for supply chain performance evaluation is based on a number of reasons. It can handle multiple entities simultaneously (Charnes et al., 1978), there is no need for prior knowledge of relationships between measures and their relative priorities, it gives a realistic and empirical benchmark for the inefficient DMUs, it can handle both qualitative and quantitative measures at the same time and it is flexible to convert into other analytical methods (Shafiee, Lotfi, et al., 2014).

Despite the promises offered by DEA for supply chain performance measurement, there are still some limitations with its application to supply chain. Goedhals-Gerber (2010) and Peng Wong and Yew Wong (2007) cite the handling of stochastic variations in inputs and outputs as an area of further research in applying DEA to supply chain performance evaluation. Traditional DEA also assumes homogenous but independent DMUs that are not linked to each other, which does not fully represent a typical supply chain. A number of hybrid DEA models have been formulated to cater for specific characteristics of the desired application areas. Network DEA, for instance, has been formulated for cases where DMUs exhibit a network format – where one DMU's outputs become another DMU's inputs, however these models have not been applied extensively for supply chain performance evaluation (Agrell & Hatami-Marbini, 2013).

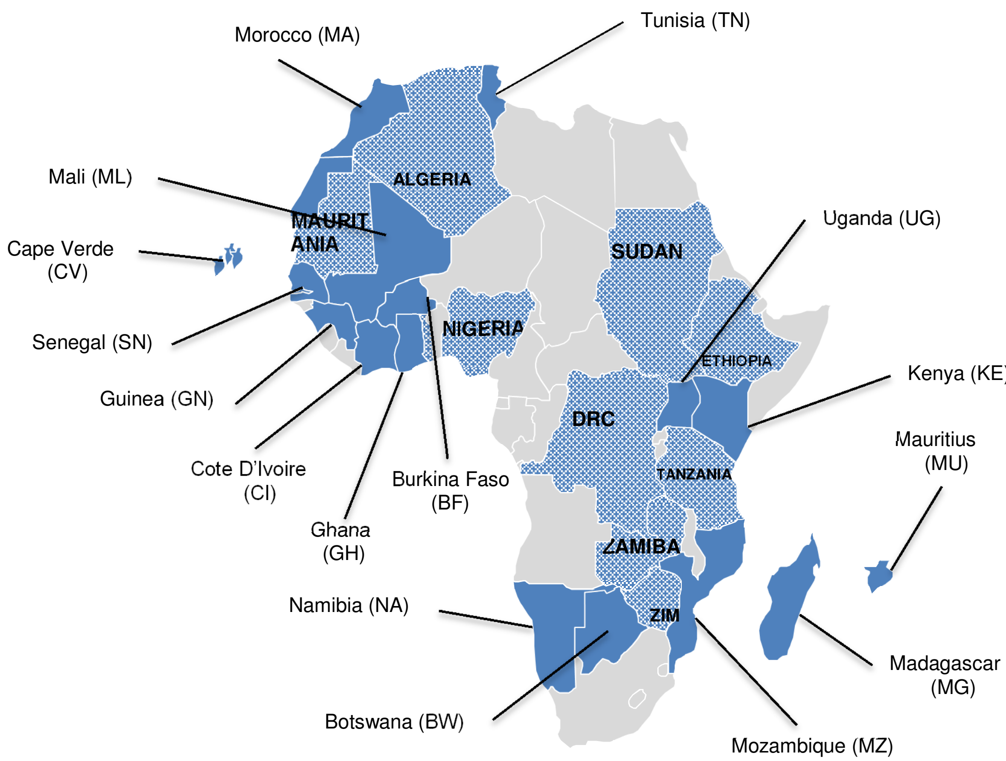
1.2.2 *Vivo Energy*

Vivo Energy (VE) is a company in the Oil and Gas industry that was established in 2011 as the sole Shell licensee to market and distribute Shell-branded products on the African continent (Vivo Energy, 2015). VE's products and services comprise commercial fuels, Liquefied Petroleum Gas, chemicals, lubricants and their vision is to be Africa's most respected energy business, achieved through a constant and reliable supply of products, on time, in full, to meet customer expectations (Vivo Energy, 2015). Vivo Energy's supply chain comprises a number of suppliers across the globe, distribution terminals and retail outlets, all linked by different modes of transport, to deliver products to the customers in the various countries they operate in. Through focused improvement, VE aspires to have the most competitive supply chain on the African continent (Vivo Energy, 2015).

VE has a direct presence in 16 African countries as shown in Figure 1. The regional distribution of VE's presence is as follows:

- **North Africa:** Morocco and Tunisia
- **East Africa:** Kenya and Uganda
- **Southern Africa:** Botswana, Madagascar, Mauritius, Mozambique and Namibia
- **West Africa:** Burkina Faso, Cote D'Ivoire, Cape Verde, Ghana, Guinea, Mali and Senegal

Figure 1: Vivo Energy footprint in Africa



Source: Vivo Energy (2015)

VE's lubricants business was chosen as a case study for this research. The VE lubricants business footprint on the African continent comprises the countries where VE is directly present and those to which lubricants are exported. Export markets in the different regions of the continent are shown in Figure 1 are as follows:

- **North Africa:** Algeria and Mauritania.
- **East Africa:** Democratic Republic of Congo (DRC), Ethiopia, Sudan and Tanzania.
- **Southern Africa:** Zambia and Zimbabwe.
- **West Africa:** Nigeria and Togo.

1.3 Problem statement

1.3.1 *Main problem*

The main problem is to propose and demonstrate a supply chain performance measurement model that evaluates the entire supply chain as well as the individual partners' contributions, based on Data Envelopment Analysis (DEA). Research shows that existing supply chain performance measures are falling short of the requirements of today's dynamic and global supply chains (Cai, Liu, Xiao, & Liu, 2009; Gunasekaran, Irani, Choy, Filippi, & Papadopoulos, 2015; Kumar & Nambirajan, 2013; MacBryde, Radnor, Shepherd, & Günter, 2006; Vaidya & Hudnurkar, 2013). A number of frameworks have been developed to measure performance in the supply chain but there is still scope for research to satisfy the need for an evaluation framework that integrates and measures performance of the organisation, its affiliates, suppliers and customers simultaneously (Agrell & Hatami-Marbini, 2013; Elrod, Murray, & Bande, 2013; Estampe et al., 2013; Gopal & Thakkar, 2012; Ramanathan, 2014).

1.3.2 *Sub-problems*

Sub-problem 1: The first sub-problem is to determine whether existing performance measures in the VE lubricants supply chain are adequate to support integration and collaboration within VE and between VE and its suppliers and customers.

Sub-problem 2: The second sub-problem is to develop a Data Envelopment Analysis (DEA) based model and use it to evaluate the performance of the Vivo Energy lubricants supply chain taking into consideration the stochastic variations of performance measures.

1.4 Significance of the study

The study seeks to provide a number of contributions to the subject of supply chain performance management. Firstly it seeks to further support the importance of integration between supply chain partners by translating it to integration of performance measurement in the supply chain. This is critical considering that the measurement of supply chain performance within and across organisations is still fragmented (Kumar & Nambirajan, 2014), incomplete and does not measure performance across the entire chain (Gunasekaran, Patel, & McGaughey, 2004). Secondly it proposes an objective method of setting performance benchmarks / targets against which to measure supply chain processes as advocated for by Gunasekaran et al. (2004), who also argue that many companies fail to maximize the potential of their supply chains due to poor target settings and control limit. Thirdly the study will assist in the building and /or testing a performance evaluation approach that assesses the contributions of all partners within a supply chain (Estampe et al., 2013). The method could also give qualitative insights on the strategic supply chain objectives of integration and collaboration as called for by (Peng Wong & Yew Wong, 2007). The supply chain management objective of equitable sharing of risks and rewards between supply chain partners via appropriate measures (Elrod, Murray, & Bande, 2013), will potentially be realised.

This study also provides a practical demonstration of objective supply chain performance management, for despite the concepts of supply chain and supply chain management being easy to understand, their implementation has not been easy for many supply chain managers (Elrod, Murray, & Bande, 2013). Supply chain managers are faced with many key performance indicators that are also intricately inter-linked, making both the selection and trade-off between these indicators, in pursuits of desired performance improvement, difficult ((Cai et al., 2009). This is compounded by the increasing complexities and dynamism of supply chains, which now calls for more robust and intelligent controls for their effective management (Qrunfleh & Tarafdar, 2014).

1.5 Delimitations of the study

This study is based on the VE lubricants supply chain on the African continent. It considers the extended lubricants supply chain comprising suppliers, Vivo Energy and some lubricants customers. It will not include Vivo Energy suppliers' suppliers or customers' customers. The impact of other exogenous factors on the performance of the supply chain will not be considered beyond the perceived influence of these factors on the performance variables under consideration. This is also influenced by the limiting data requirements of the Data Envelopment Analysis methodology, which dictates that a limited number or performance indicators be used to characterise supply chains.

1.6 Definition of terms

Supply chain: a supply chain is series of operational processes that deliver products and services from suppliers to customers (Halldorsson et al., 2007;

Saetta, Paolini, Tiacci, & Altiok, 2012; Tavana, Mirzagoltabar, Mirhedayatian, Saen, & Azadi, 2013).

Extended supply chain: an extended supply chain is a group of organisations; a focal firm and its business partners (its suppliers, affiliates and customers), offering products or services to final customers. The extent of the chain is a matter of choice; it can extend to suppliers' suppliers and beyond and likewise can extend to customers' customers and beyond (Halldorsson et al., 2007).

Supply chain management: supply chain management is the effective control and management of the flows that happen through the supply chain – materials and products, information and money (Wu et al., 2014). It can also be considered as a systematic and integrative management and coordination of the traditional operational functions internal to the focal firm and external partners with the objective of improving the long-term business performance of all (Elrod, Murray, & Bande, 2013).

Supply chain performance: the definition of performance is generally ambiguous (Silvi, Bartolini, Raffoni, & Visani, 2015). For the supply chain, performance is measured against responsiveness to customer requirements and associated costs (Estampe et al., 2013; Pero, 2010), reliability to deliver as planned, flexibility to respond to changes in customer demand and efficient asset utilisation (APICS Supply Chain Council, 2015)

1.7 Assumptions

The following assumptions have been taken in this research:

- The Vivo Energy lubricants supply chain performance can be fully accounted for through measurements that are monitored and tracked by Vivo Energy, their suppliers and customers.

- Supply chain processes in the VE lubricants supply chain can be wholly characterised through theoretical mathematical models.
- VE lubricants businesses in the different countries are homogeneous and comparable in terms of their performance and any underlying factors that influence performance. This means that any best practices applied in one country are assumed to be applicable in any other country in pursuit of performance improvement.
- The outcome of the analysis can be used for the analytical generalisation of the application of DEA for evaluation of all supply chains under similar operating conditions.

CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

In this section the background of the supply chain concept is introduced as an evolution of operations management. Both the supply chain and the management of the supply chain (supply chain management) are defined and the growing strategic importance of supply chain management for businesses in the 21st century is presented. Integration and collaboration between supply chain partners are identified as some of the key objectives of supply chain management. Together with the challenges of integration and collaboration, the challenges of performance measurement in the supply chain are assessed and a proposition that existing performance measures and methods do not do enough to support the supply chain objectives of integration and collaboration made. Data Envelopment Analysis (DEA), a linear programming based performance evaluation method, is defined its basics are discussed. Another proposition is made that DEA can be used to enhance current measures and measurement methods to evaluate performance across the supply chain in an integrative and equitable way.

2.2 The Supply Chain Imperative

The field of operations management has traditionally been associated with the transformation activities that turn resources into goods and services for customers (Slack, Chambers, & Johnston, 2007). The operational imperative of effective and efficient transformation of inputs into quality outputs for consumers – known as operational excellence, has played a role in giving firms competitive advantage against competition for many years (Goedhals-Gerber, 2010). Operational excellence is achieved through the effective control and management of functional processes that constitute the organisation.

Globalisation has brought about new opportunities of previously unknown foreign markets and more competitive suppliers possibly based in foreign and low cost geographies. This has resulted in the lengthening of the organisational links that deliver products and services to customers. With this extension of the links, it has also become important to effectively control and manage that chain of organisations in order to meet the goals of customer satisfaction. Organisations that do not manage these links with their suppliers and customers are becoming more and more vulnerable to their counterparts with stronger links (Manzoni, 2007). Therefore it has become an imperative to effectively control and manage the chain of organisations as a source of competitive advantage – the supply chain imperative.

2.2.1 *Supply Chain: Definition*

The importance of the supply chain has seen a significant proliferation of its definition. Halldorsson et al. (2007) define a supply chain as a meta-organisation composed of many independent firms bound together by inter-organisational working relationships and business processes that extent beyond the traditional boundaries of each organisation. Saetta et al. (2012) define it as a network of business entities with independence and autonomy but still bound by a common objective to work in unison. Tavana et al. (2013) see it as a network, comprising suppliers, manufacturers and distributors, which transforms raw materials into finished products and delivers these to customers.

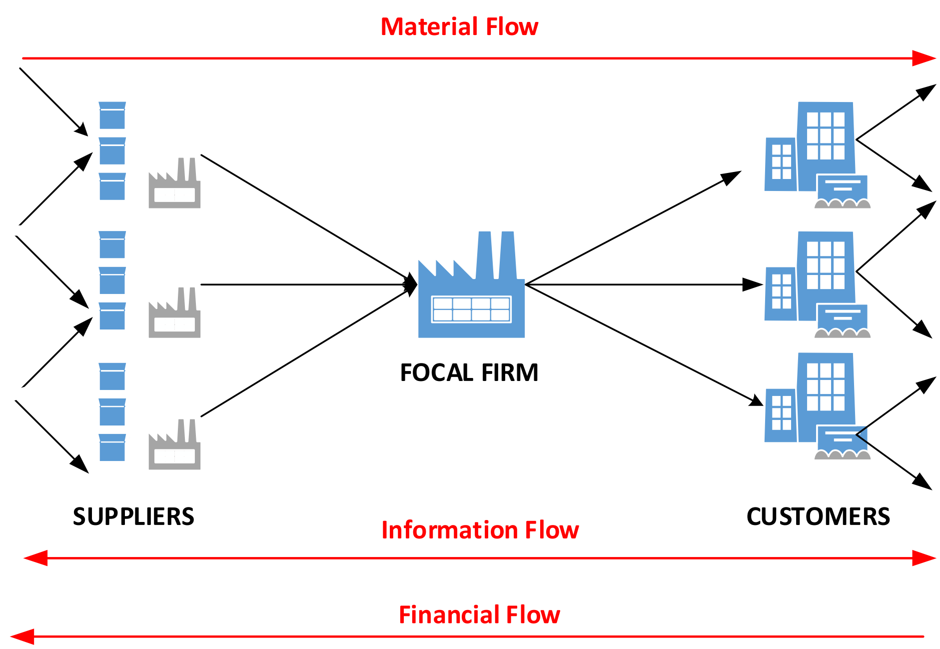
All definitions of the supply chain however touch on all or some of the following key attributes:

- A supply chain is composed of many functional and / or organisational entities (Halldorsson et al., 2007; Saetta et al., 2012; Tavana et al., 2013)
- There are three main flows in a supply chain; the flow of materials and goods, the flow of information and the flow of finances (Tavana et al., 2013).

- The extension of the supply chain is situation dependent; it can be defined within the scope of one organisation or beyond the boundaries of the focal organisation to include immediate suppliers and customers. It can also be defined beyond the immediate suppliers of the focal firm (suppliers' suppliers) and immediate customers of the firm (customer's customers) (Halldorsson et al., 2007).

Figure 2 shows a typical supply chain and the flows that occur through it – the material flow, information flow and financial flow.

Figure 2: Typical supply chain and the main flows

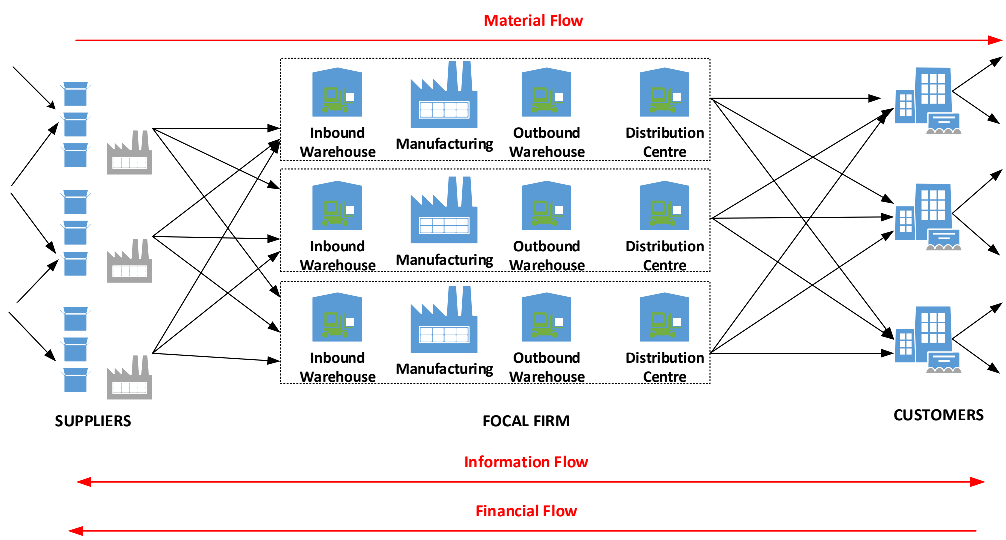


Source: Own Illustration

The focal firm may have multiple sub-entities; inbound and outbound warehouse operations, manufacturing facilities and distribution centres. Suppliers may supply to multiple manufacturing sites of the organisation and from the outbound operations the firm might also operate distribution centres in different geographical regions. All these additional functional entities, their operational performance objectives and the processes that link them to each other, result in increasing complexity associated with the coordination of their activities, processes and objectives.

Figure 3 shows the detail and potential complexity of the supply chain when one considers the functional entities within the focal firm and their interaction with each other and with external partners.

Figure 3: Supply chain showing some functional entities of the focal firm



Source: Own Illustration

2.2.2 *Supply Chain Management: Definition*

There are a number of definitions of supply chain management. In their definition of supply chain management, Wu et al. (2014) highlight it as the effective control and management of the three flows (goods, information and finance) between supply chain partners. Elrod et al. (2013) simplify it to a set of management principles meant to make the supply chain a success. Citing the prevalence of multiple business relationships in the supply chain Lambert and Cooper (2000) define supply chain management as the management of these relationships. Goedhals-Gerber (2010) summarises many other definitions by different institutions and researchers. In simple terms, controlling and managing the flows that occur through a supply chain for effective and efficient delivery of the supply chain's objectives constitutes supply chain management.

Supply chain management has become a source of competitive advantage and many organisations now appreciate its strategic importance (Shi & Yu, 2013). It is becoming evident that the competitiveness of businesses is not only dependent on the activities that happen within the traditional boundaries of the organisation; significant value is also now created outside this traditional boundary (Halldorsson et al., 2007). While the separation of operational and support activities across many organisations enables specialisation and hence enhances efficiency and operational excellence, it also implies that competition to meet customer expectations is no longer on the basis of quality alone but on the basis of how timeously products are delivered to customers (Goedhals-Gerber, 2010). Therefore as firms strive to meet customer demand timeously, they are forced to compete as part of a supply chain rather than as individual entities (Wu et al., 2014). Integration and collaboration along the supply chain is now imperative for business's survival.

2.2.3 *Supply Chain Integration*

One of the critical elements of supply chain management is the integration between an organisation and its supply chain partners; effective and efficient supply chain management is largely built on how well a business integrates and collaborates with its suppliers and customers (Kumar & Nambirajan, 2013). Ramanathan (2014) talks of the 21st century supply chain as an integrative and value-adding supply chain whose main objectives are to increase customer satisfaction, increase service and reduce costs. He further argues that these objectives of the supply chain can no longer be a stand-alone effort of a single organisation in the chain but have to be delivered through integration between the supply chain partners. The increasing manifestation of supply chain integration efforts can be seen in the many best practices of supply chain management that are based on the principles of integration – Vendor Managed Inventory (VMI), outsourcing, Collaborative Planning Forecasting and Replenishment (CPFR), Vendor Collaboration, Electronic Data Interchange (EDI) and Customer Relationship Management (CRM). Many companies have therefore established collaborative arrangements with their supply chain partners in an effort to achieve the benefits of integration (Ramanathan & Gunasekaran, 2014).

Supply chain integration is mainly achieved via the use of information technology systems that help with real time sharing of relevant information across the chain (Qrunfleh & Tarafdar, 2014). Sharing of real time information between supply chain partners facilitates the smooth flow of goods through the supply chain and enhances the demand planning forecasting processes (Ramanathan, 2013). Ramanathan and Gunasekaran (2014) list seven dimensions of collaboration – sharing of information, alignment of goals, synchronised decision-making, alignment of incentives, sharing of resources, communication and joint learning.

Shi and Yu (2013) identify some significant empirical evidence showing the positive correlation between supply chain performance and the financial performance of the firm. They conclude by arguing that the optimization of the financial performance should be the ultimate goal of supply chain management. They also identify the critical drivers of supply chain management that ensures financial performance – sourcing strategy, integration, information technology and external relationships. One can argue that all these point towards an extended supply chain and the integration of its partners through technology and relationships.

2.2.4 *Challenges of Supply Chain Integration*

Despite its growing and apparent importance, integration along the supply chain is not easy to achieve. Many business shy away from formal collaborative relationships with their supply chain partners due to lack of understanding of collaboration and its positive impact on profitability (Ramanathan & Gunasekaran, 2014). Since most of the players in the supply chain are autonomous business or functional entities, they are more likely to make decisions on the basis of what they perceive to be best for themselves rather than what is best for the entire supply chain (Saetta et al., 2012). Goedhals-Gerber (2010) also notes that organisations are more inclined to try and optimize their own performance with little regard to the optimization of the supply chain – they pursue their own profitability objectives, objectives that do not necessarily complement the objectives of the supply chain.

Some of the key barriers to supply chain integration are mistrust between partners, too much internal focus, poor definition of benefits and costs along the chain, over-reliance on relationships and mismatch in priorities of the partners (Ramanathan, 2014). With supply chains becoming more complex as they span across the globe, they also become more difficult to manage (Qrunfleh & Tarafdar, 2014), which also compounds the barriers to integration. In some instances the objectives of the different supply chain partners are disparately different; for instance Goedhals-Gerber (2010) highlights that the key supply chain players in South Africa are in both private and public sectors with totally different objectives. Private institutions will advance profitability while public institutions advance social objectives.

To deliver full supply chain integration, one would need a way of measuring and quantifying such integration and it implications on the performance of both the supply chain and the individual partners (Goedhals-Gerber, 2010). Demonstrating the actual or potential benefits of integration and collaboration will go a long way in fostering integration between supply chain partners (Ramanathan, 2014). Clearly, performance measurement is a key area of consideration in trying to achieve supply chain integration. Agrell and Hatami-Marbini (2013) assert performance evaluation that caters for the supply chain and the independence of the supply chain players as the most important process to ensure the competitiveness of ultimate survival of the supply chain.

2.3 Performance Measurement

Performance measurement can be defined as the quantification of the efficiency and effectiveness of a process (Gunasekaran & Kobu, 2007). It is an important aspect of business management and many companies fail to maximise their potential due to poor performance measurement systems (Gunasekaran & Kobu, 2007; Gunasekaran et al., 2004). According to Gunasekaran and Kobu (2007), Bhagwat and Sharma (2007) and Goedhals-Gerber (2010), good performance measurement should achieve the following:

- Enable sound decision-making by providing facts as opposed to subjective basis.
- Assess the performance against the strategic objectives
- Give a diagnosis of performance issues and identify problem areas for correction and improvement.
- Identify areas where objectives are being met.
- Identify performance gaps against benchmarks.
- Give motivation and justification for continuous improvement efforts.

2.3.1 *Supply Chain Performance Measurement*

The main variance between generic performance measurement and supply chain performance measurement is rooted in the extended nature of supply chains which incorporates suppliers, distributors, customers etc. into the scope of assessment (Khare, Saxsena, & Teewari, 2012). Due to the complex nature of supply chains now and the additional requisite of supply chain integration and collaboration, there are additional requirements for an effective supply chain performance measurement system. An effective supply chain performance measurement system would also need to satisfy the following additional requirements:

- Assess the performance of the supply chain as a whole to avoid optimising parts of the supply chain at the expense of the entire supply chain (Vaidya & Hudnurkar, 2013).
- Set objective benchmarks of performance for all supply chain partners (Gunasekaran et al., 2004).
- Assess the contribution of each supply chain partner to the performance of the supply chain (Estampe et al., 2013).
- Ensure that the risks and rewards across the supply chain are shared equitably according to the integration and collaboration philosophy behind supply chain management objectives (Elrod, Murray, & Bande, 2013).
- Should be dynamic and not static in order to deal with the dynamic nature of the supply chain (Cai et al., 2009).
- Should be accurate and reflective of actual performance and thereby assist with the selection of the appropriate strategies and tactics leading to increased benefits and reduction of the negative impacts of poor performance (Gunasekaran et al., 2015)

2.3.2 *Existing Supply Chain Performance Measurement*

A number of models and frameworks have been used to measure the performance of supply chains. Estampe et al. (2013) summarise models developed from the 1980s to around 2010. They classify these models into two groups - those oriented towards internal organisational assessment and those geared towards inter-organisational analysis. The internally oriented performance measurement systems are relevant to organisations still targeting to align their internal supply chain processes. They are geared for measuring autonomous organisations and hence may fail to effectively function in complex supply chain scenarios (Estampe et al., 2013). For the purpose of this research therefore, and in line with the philosophy of supply chain integration, two models geared towards inter-organisational analysis will be considered.

The Balanced Scorecard (BSC)

The Balanced Scorecard (BSC) was developed by R. Cooper and Kaplan (1992) to assist managers deal with the proliferation of performance measures by forcing them to pick only a few measures that are critical to the performance of the business. It defines four dimensions that give a balanced assessment of the organisation's performance – the financial perspective, the customer perspective, the internal business perspective and the innovation and learning perspective. The Balanced Scorecard has been used as a basis for supply chain performance evaluation; for instance, it has been used to classify existing supply chain measures into the four classes of the BSC (Bhagwat & Sharma, 2007) and has also been used together with Analytic Hierarchy Process (AHP) to evaluate supply chain performance (Sharma & Bhagwat, 2007).

Despite its popularity and wide application the BSC has been found to be inward focused (Estampe et al., 2013) and unable to answer a number of theoretical questions related to supply chain performance (Cunha Callado & Jack, 2015). It also relies on the definition of the causality between performance measures and the four dimensions and due to the complex inter-causal relationships between supply chain measures, its difficult to definitively allocate these measures to the four classes (Bhagwat & Sharma, 2007).

Supply Chain Operations Reference (SCOR) Model

The Supply Chain Operations Reference (SCOR) model is a hierarchical model for analysing the supply chain. It classifies all supply chain processes under the broad processes of PLAN, SOURCE, MAKE, DELIVER, RETURN and ENABLE. The Supply Chain Council developed the first SCOR model in 1996 and ever since the model has been enhanced and improved in order to cater for all supply chains from different industries. Performance evaluation of the supply chain via the SCOR model is done on the basis of the following attributes and associated performance measures in Table 1:

Table 1: SCOR Model performance attributes and measures

Attribute	Attribute Description	Performance Measures
Reliability	The ability of the supply chain to perform and give outcomes as expected and predicted.	Perfect Order Fulfilment
Responsiveness	The speed at which the supply chain responds to customer demand and provides the required products.	Order Fulfilment Cycle Time
Agility	The supply chain's ability to respond to operational and external perturbations and maintain competitive advantage.	Upside supply chain flexibility Upside supply chain adaptability Downside supply chain adaptability Overall value at risk
Costs	Costs incurred while operating the supply chain.	Total Cost to Serve
Asset Management Efficiency	The supply chain's ability to efficiently utilise its assets.	Cash-to-Cash cycle time Return on supply chain fixed assets Return on working capital

Source: APICS Supply Chain Council (2015)

The SCOR model has got the advantages of applicability to all industries including service companies, applicability to tactical and operational levels and its recognition of other supply chain players (Estampe et al., 2013). However, with over 250 potential performance measures when exploded across all levels of the hierarchy, it is possible that the choice of measures and their interdependencies within the firm and across the chain become a challenge.

Juxtaposing current supply chain performance measurement models and the ideal requirements reveals that there are still some challenges negatively impacting the accurate assessment of supply chain performance.

- Kumar and Nambirajan (2013) and MacBryde et al. (2006) argue that the measurement of supply chain performance is still fragmented within organisations and across the supply chain with no vision for formulation of effective metrics.

- Vaidya and Hudnurkar (2013) note that performance measurement is still largely intra-organisational and gives organisations relative prominence over the supply chain and therefore making it difficult to optimise of the entire supply chain.
- The proliferation of KPIs noted by R. Cooper and Kaplan (1992) still continues; (Cai et al., 2009) identify the increasing number of KPIs as posing difficulties in both selection and trading-off in order to obtain the required improvement. The causal relationships between many of the supply chain KPIs are difficult to determine and quantify (Cai et al., 2009).
- In some companies the pursuit of supply chain integration strategies like outsourcing is hampered by lack of appropriate performance measures that can assist with decision-making (Gunasekaran et al., 2015). Gunasekaran et al. (2015) highlight that the costs associated with integration are sometimes under-estimated and high.

Considering that most of the researches on supply chain performance have been conducted outside Africa (Shi & Yu, 2013) it is conceivable to propose that the measurement of supply chain performance in Africa is still not effective enough to support the philosophy of integration. Gopal and Thakkar (2012) also suggest to contemporary researchers to apply their models of supply chain performance in both developed and developing countries in order to comprehend the differences related to the different contexts.

2.3.3 *Proposition 1*

Supply chain performance measurement in the Vivo Energy lubricants supply chain is still fragmented across the supply chain and does not foster integration between the supply chain participants.

2.4 Supply Chain Efficiency

Kaplan and Norton (1993) noted the importance of introducing new measures and metrics to assess new goals, processes, initiatives and strategies. With regards to the supply chain, one can argue that its growing importance and complexity demands an evolution in the associated performance measurement. Gunasekaran and Kobu (2007) question the suitability of contemporary supply chain performance measures in assessing supply chains that are now complex and span across the globe.

Goedhals-Gerber (2010) in assessing South Africa's supply chains employs the concepts of efficiency and effectiveness. Defining effectiveness as measuring fulfilment of the supply chain purpose of giving desired service level, and efficiency as the economy of resource utilisation in fulfilling the purpose, Goedhals-Gerber (2010) uses the existing performance measures to evaluate the efficiency of supply chains in South Africa. One can argue that perhaps in the supply chain context, where supply chain partners depend on each other, one of the best ways of measuring the performance is by use of the efficiency concept. This way assessment of efficiency can be carried out on all supply chain partner as well as on the entire supply chain. By assessing how efficiently supply chain partners utilise supply chain resources and other inputs, more clarity can be given on contributions by each supply chain partner; and perhaps more harmony will follow between the partners.

2.5 Data Envelopment Analysis (DEA)

Data envelopment analysis (DEA) is a multi-factor non-parametric linear programming performance evaluation method originally developed by Charnes et al. (1978) to study and measure the relative performance of a homogeneous set of Decision Making Units (DMU). A DMU can be a function, business unit, an organisation or supply chain that transforms inputs into outputs and whose performance has to be evaluated on the basis of multiple measures and benchmarked against other similar peers. DEA evaluates performance by providing an empirical estimate of the relation between observed inputs and outputs of the DMUs. The basis of DEA performance evaluation is the assessment and benchmarking of DMU efficiencies – DEA evaluates whether and how each DMU converts its inputs into outputs in an optimal way. In DEA terms, efficiency is defined as the degree to which each DMU optimally utilizes resources to produce outputs (Cooper, Seiford, & Tone, 2006). It is the ratio of the output to the input. In the case of multiple inputs and outputs DEA sums the inputs and gives the efficiency score according to the formula below (Charnes et al., 1978).

$$Efficiency = \frac{weighted\ sum\ of\ outputs}{weighted\ sum\ of\ inputs}$$

The calculation of DMU efficiencies, DEA identifies both efficient and inefficient DMUs among the sample through comparison of their efficiencies (Shafiee, Lotfi, et al., 2014). The identified efficient DMUs become benchmarks for the inefficient DMUs and through cooperation and collaboration best practices can be shared and used to improve the efficiencies of the inefficient DMUs.

2.5.1 *DEA Basics*

A simple example that will be used to explain the basics of DEA; shown in **Table 2**, has five DMUs that convert a single input into a single output and the calculation of efficiency scores. This example is used to illustrate and explain the basics of DEA that follow in this section. It is important to note that DEA models come in various forms and the variation between the models depends on a number of factors – orientation, return-to-scale, nature of return-to-scale etc. Some of these models are explained in more detail later in this section.

Table 2: Single input and output DMUs and efficiency example

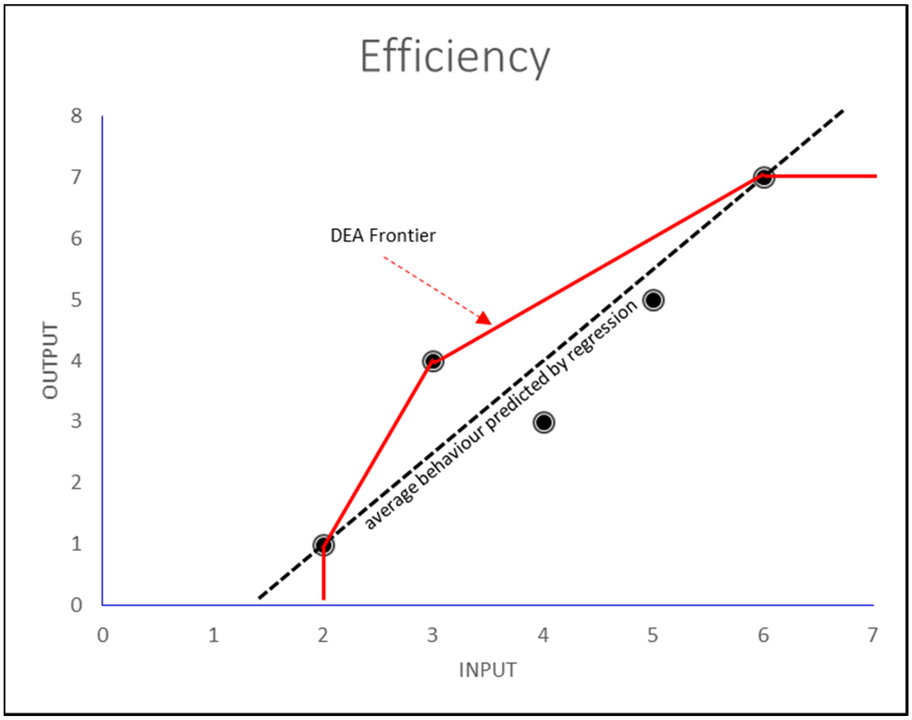
DMU	INPUT	OUTPUT	EFFICIENCY RATIO	EFFICIENCY %
A	2	1	1/2	50%
B	6	8	4/3	125%
C	5	5	5/5	100%
D	4	3	3/4	75%
E	6	7	7/6	117%

Source: Own illustration

Frontier Approach

DEA is a frontier based analysis as opposed to central based statistical analyses (Gregoriou & Zhu, 2005) – instead of trying to curve-fit the best fitting line through observed data employing the common statistical approach of predicting average behaviour, DEA tries to floats a piece wise surface that defines the efficiency frontier on top of the data observations (Charnes et al., 1978). Connecting those DMUs whose observed output is the best for any given level of input forms the frontier. In Figure 4 the five DMUs in **Table 2** are plotted on a chart that shows the input on the x-axis and the output on the y-axis. It shows the difference between the central tendency-based predicted behaviour and DEA's frontier approach.

Figure 4: DEA frontier approach versus statistical approach

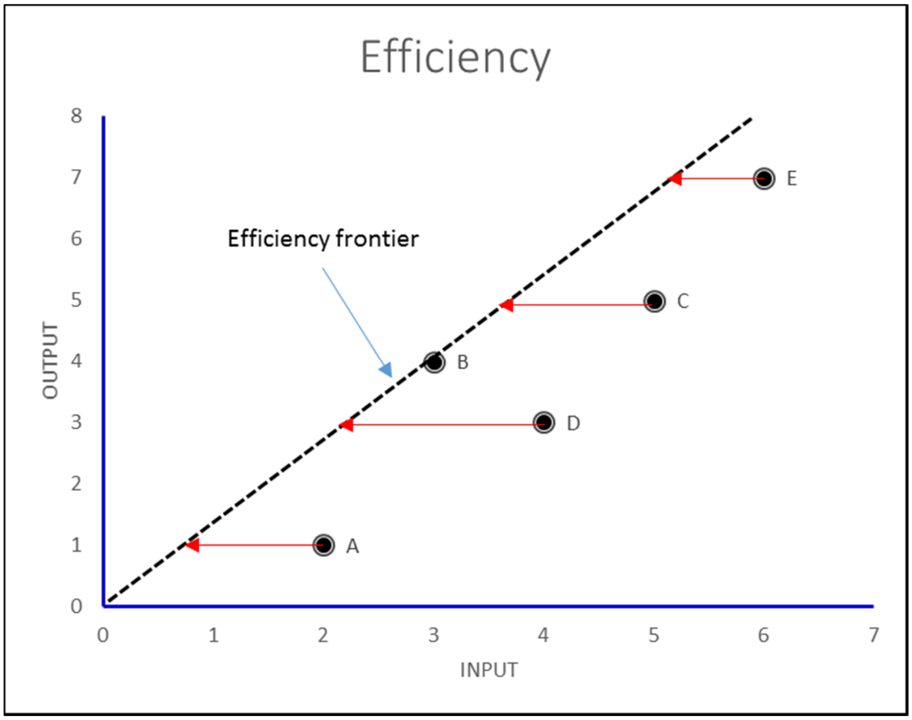


Source: Gregoriou and Zhu (2005). Own illustration

Orientation: Input or Output

The orientation of a DEA model is based on whether the model and analysis is done with the primary objective of minimizing inputs (while holding output constant) or maximizing output (while holding input constant). In other words all inefficient DMU can be improved by either cutting back on input or by increasing output as shown in the charts that follow. In the input orientation, as shown in Figure 5, all DMUs, except B, which is already on the efficiency frontier, can reduce their inputs without while maintaining the same output to become efficient. A DEA model whose primary objective is to reduce inputs is said to be input-oriented and the amounts by which inputs can be reduced in order to achieve full efficiency are called input excesses.

Figure 5: Input-oriented DEA

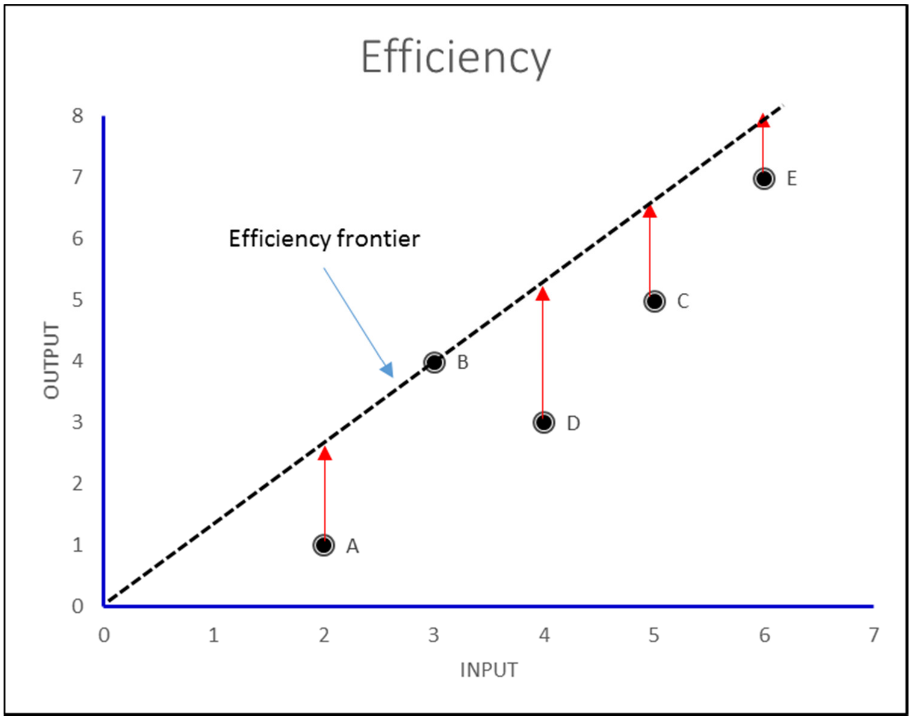


Source: Cooper et al. (2006). Own illustration

Conversely, the same DMUs can increase their outputs without increasing their input as shown in Figure 6 below. So a DEA model whose primary objective is to increase outputs, while keeping inputs unchanged, is said to be output-oriented. The amounts by which outputs can be increased to achieve full efficiency are called output shortfalls.

The efficiencies of the DMUs will be the same whether the model employed is input-oriented or output-oriented.

Figure 6: Output oriented DEA



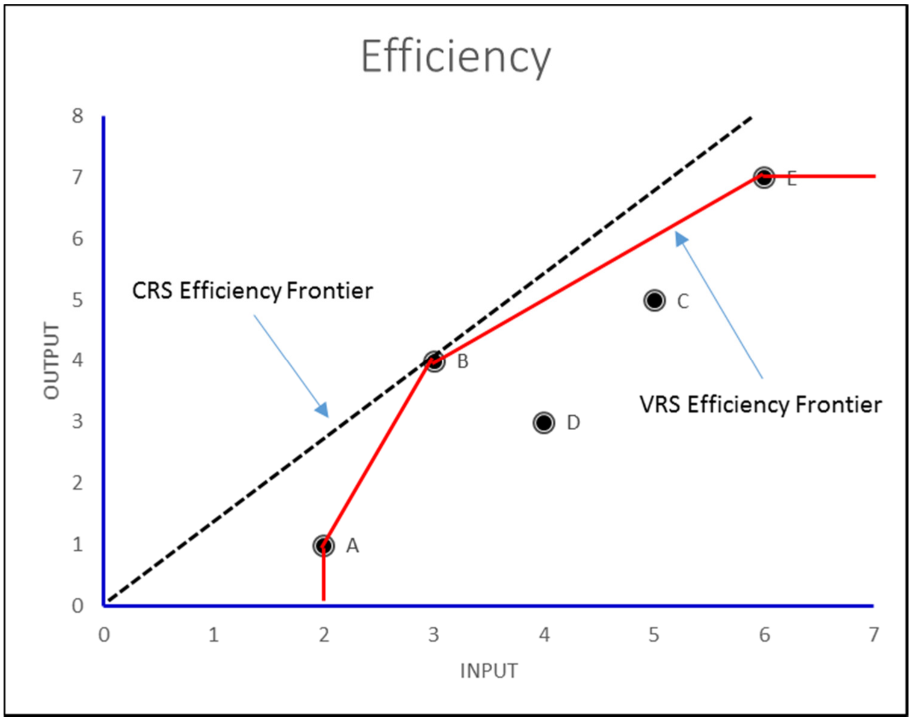
Source: Cooper et al. (2006). Own illustration

Returns to Scale (RTS) – Fixed or Variable:

In the examples of orientation shown in Figure 5 and Figure 6, the 'return' that constitutes the efficiency frontier (the maximum output per unit of input) has been assumed to be constant. This is based on an underlying assumption that all DMUs are operating at optimal scale with no additional efficiency to be gained or lost by each DMU due to its size (scale). This is the simplest form of DEA, called Constant Returns to Scale (CRS), introduced by Charnes, Cooper and Rhodes (CCR) in 1978 and hence is called the CCR Model.

The efficiency frontier can also comprise a number of DMUs with varying returns. It therefore becomes piecewise linear and concave in nature – returns vary on the different linear sections of the frontier and therefore it is called Variable Returns to Scale (VRS). This model was proposed as an extension of the CCR model by Bankers, Charnes and Cooper (BCC) and hence is called the BCC model. Figure 7 below shows the difference between CRS and VRS efficiency frontiers.

Figure 7: Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS)



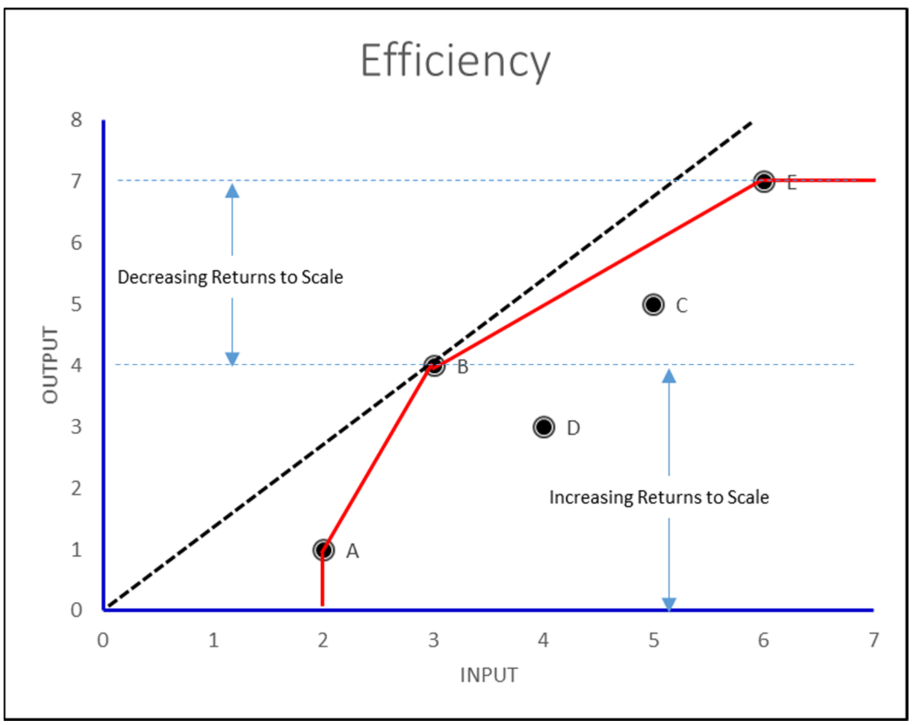
Source: Huguenin (2012). Own illustration

The gap between the two curves is due to the sizes of the DMUs. All DMUs on the VRS efficiency frontier (A and E) can only become CRS-efficient by changing their scale / size. Their inefficiencies are due to scale problems (Huguenin, 2012). However those DMUs, which are neither on the CRS nor on the VRS efficiency frontiers, have two sources of inefficiencies – scale inefficiency and inefficiency attributable to poor management of their processes of producing outputs from inputs. Therefore CRS efficiency, referred to as Total Efficiency is made up of two components – scale efficiency and 'pure' efficiency (VRS efficiency) (Huguenin, 2012).

Nature of RTS

Another point to note is that DMUs A and D have scale inefficiency in a region where an increase in scale will improve their efficiency – they are experiencing increasing returns to scale (IRS) or economies of scale. This means that A and D's outputs can be increased at a higher rate than their inputs because they still have not reached their optimal scale. This increasing 'returns' to scale happens only until DMU's B, the only DMU with the optimal scale. On the other side of DMU B are DMUs C and E with decreasing returns to scale (DRS). DMUs C and E are in a region where their outputs decrease with scale – their inputs rise at a higher rate than the corresponding output rate of increase. So in order to be more efficient they have to reduce their scale. Figure 8 shows the IRS and DRS regions of the frontier plot.

Figure 8: Decreasing Returns to Scale (DRS) and Increasing Returns to Scale (IRS)



Source: Huguenin (2012). Own illustration

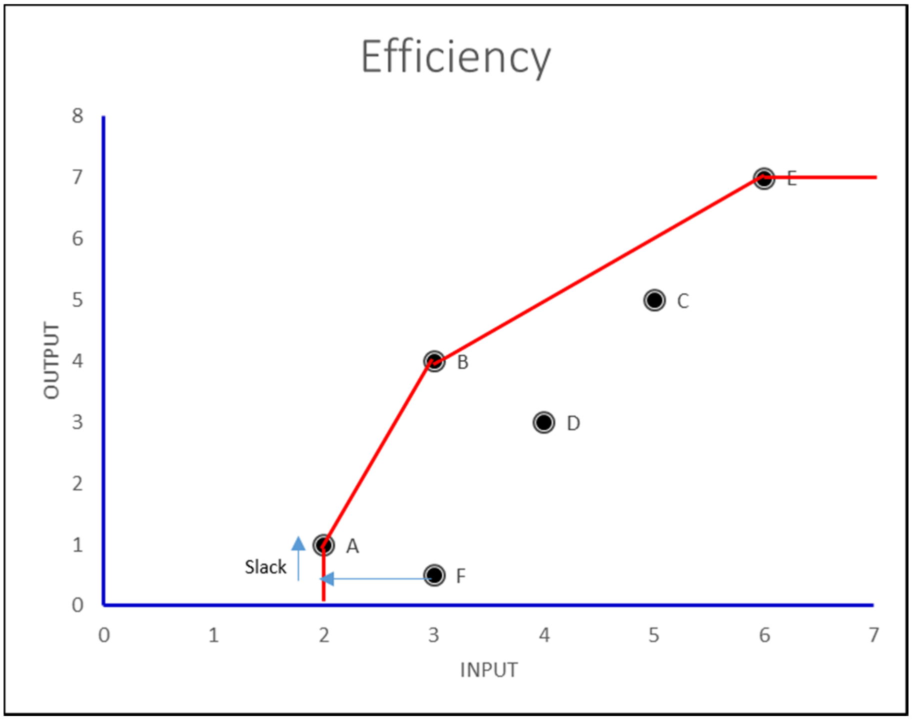
Peers & Benchmarks

As highlighted earlier, DEA performance evaluation identifies both efficient and inefficient DMUs. For each inefficient DMU, DEA identifies the closest benchmark or peer efficient DMUs. In order to improve its performance, an inefficient DMU has to emulate its peers. Since one of the underlying assumptions of DEA is that DMUs are homogenous and similar, emulation of best practices of efficient DMUs is assumed to result in performance improvement of inefficient DMUs.

Slacks

Some positions are inefficient despite them falling on the efficiency frontier (Cooper et al., 2006; Huguenin, 2012). For instance, if we consider an additional DMU, F, as shown in Figure 9, an input oriented DEA analysis would suggest that F should reduce its input to 2 and thus become efficient. At that point on the frontier however, one realizes that F can still increase its output to the same level as DMU A without having to increase its input. That additional inefficiency is called ‘slack’. In general, any DMU falling on the piecewise segment of the frontier that runs parallel to the axes has got some slack. The presence of slacks implies that an input-oriented DEA model does not necessarily show input excesses only; it can also show output shortfalls. The same can be said about an output-oriented DEA model; it can also show input excesses due to the presence of slacks.

Figure 9: Demonstration of slack



Source: Huguenin (2012). Own illustration

Window Analysis

The basic DEA model assumes that the inputs and outputs of the DMUs have been observed only once. In reality however, the performance of DMUs is likely to be constantly under observation over time. Efficiency measurements could also be driven by interest in performance improvement observation over time rather than snap shot view of performance. Therefore, one of the extensions of the DEA methodology is designed to cater for this. Window Analysis is an extension of DEA where observations of multiple periods of the same DMU are treated as individual “DMUs” which are compared and contrasted against each other (Cooper, Seiford, & Zhu, 2011). Besides giving insights on the trend of performance improvement (or decline), window analysis also gives insights on the stability of the performance of the DMUs. Cooper et al. (2006) present window analysis as an area that still requires further research to establish the full theoretical implications of this approach.

2.5.2 *Mathematical form of DEA*

The relative efficiency of each DMU is calculated according to Charnes et al. (1978)'s model below.

Assume that there are *n* DMUs and each DMU is converting *m* inputs into *s* outputs the relative efficiency of the p^{th} DMU, E_p is calculated as follows:

Maximize $E_p = \frac{\sum_{k=1}^{s} v_k}{\sum_{j=1}^{m} u_j} \frac{y_{kp}}{x_{jp}}$

Subject to the following constraints

$\frac{\sum_{k=1}^{s} v_k}{\sum_{j=1}^{m} u_j} \frac{y_{ki}}{x_{ji}} \leq 1$ for all other DMUs

$v_k, u_j \geq 0$ for all k and j

Where

$k = 1 \; to \; s,$

$j = 1 \; to \; m,$

$i = 1 \; to \; n,$

$y_{ki} = output \; k \; from \; DMU \; i,$

$x_{ji} = input \; j \; used \; by \; DMU \; i,$

$v_k = weight \; applied \; to \; output \; k,$

$u_j = weight \; applied \; to \; input \; j,$

The above format can be changed into a linear programming format by constraining either the denominator or the numerator to 1. The objective therefore becomes either to minimize the weighted input or maximize the weighted output. The new linear program format of DEA is as below:

Maximize $E_{p=} \sum_{k=1}^{s} v_k y_{kp}$

Subject to $\sum_{j=1}^{m} u_j x_{jp} = 1$

$\sum_{k=1}^{s} v_k \, y_{ki} - \sum_{j=1}^{m} u_j \, x_{ji} \leq 0$

$v_k, u_j \geq 0$ for all k and j

This can be expressed in the dual linear program form below

Minimize $\quad E_{p=}\theta_0$

Subject to $\quad \theta_0 x_{jp0} \geq \sum_{j=1}^{n} \lambda_j \, x_{jp}$

$y_{ki0} \leq \sum_{j=1}^{n} \lambda_j \, y_{ki}$

Where $\quad \lambda_j \geq 0, for\ all\ j$

It is important to note that the above assumes a CRS model. In the case of VRS an additional constraint shown below is applied to the linear program equation.

$$\sum_{j=1}^{n} \lambda_j = 1$$

Weights

The weights that are determined by DEA are the optimal weights that result in a DMU maximizing its efficiency. Each individual weight shows how highly the corresponding input or output is evaluated relative to the others (Cooper et al., 2011). The relative importance of each input and output can therefore be inferred from the weights. Although DEA calculates the optimal weights, it also allows constraints to be applied to the weights based on external knowledge. For instance the relative importance of inputs or outputs can prompt a constraint to be applied so that the weights reflect that relative importance.

Prior Knowledge

DEA allows incorporation of some prior knowledge about the DMUs being evaluated or their operating environment. Cooper et al. (2011) give three situations that may warrantee that prior knowledge be used to exert some restrictions to DEA – additional information that may be incorporated into the model, management's preference on the weighting or relative importance of inputs and outputs or a small sample of DMUs that may cause DEA to fail to discriminate between the DMUs.

2.5.3 *DEA Data Requirements*

The following are the data requirements for DEA according to Cooper et al. (2006) and Cooper et al. (2011):

1. **Homogeneity:** All DMUs should be similar and they should have the same number of inputs and outputs.
2. **No sampling error:** Because DEA is a deterministic and non-parametric technique (as opposed to statistical) its results are particularly prone to measurement error (Cooper et al., 2006). Therefore it is critical to check for outliers in the inputs and outputs of DMUs before applying DEA to ensure that the results are not biased.
3. **Number of inputs, outputs and DMUs:** DEA is sensitive to the number of inputs, outputs and DMUs in the calculation. Generally, increasing the sample size while holding the number of inputs and outputs will reduce the DEA efficiency scores since increasing sample size offers more opportunity for DEA to find peers. Conversely, reducing the sample size will increase the DMU efficiency scores (Cooper et al., 2006). Similarly, increasing the number of inputs and outputs without increasing the number of DMUs will tend to increase the DEA efficiency scores since increasing inputs and outputs offers more uniqueness to DMUs (Cooper, Seiford, & Tone, 2007).

   As a guide line Cooper et al. (2007) suggest that for n DMUs with m inputs and s outputs:

$$n \geq \max[m \times s, 3(m+s)]$$

4. **Discretionary variables:** DEA assumes that all variables are under the control of management hence it's possible to either reduce inputs or increase output as a way of improving efficiency. Variables that are controllable by management are called discretionary variables. Non-discretionary variables are variables that impact the performance of the DMUs but are exogenous and hence not controllable by management. The traditional DEA approach does not cater for non-discretionary variable although extensions of DEA have found a way around catering for exogenous factors' impact. Besides ensuring that DMUs under comparison are similar and have similar operating environment Cooper et al. (2006) also suggests including the operating environmental characteristics as part of the DEA calculation. Alternatively, Cooper et al. (2011) suggest a two-step procedure where the efficiency scores are adjusted through the use of some relationship between the exogenous variable and the efficiency. The relationship can be determined via a statistical method like a regression analysis.

2.5.4 *DEA Applications*

DEA has been used a lot to assess performance in the banking, health, agriculture, education and transportation sectors (Liu, Lu, Lu, & Lin, 2013). Its application in the area of supply chain management has been relatively slower but it has been used by a number of researchers to measure the efficiency of supply chains. Peng Wong and Yew Wong (2007), Tavana et al. (2013) and Goedhals-Gerber (2010) have demonstrated the use of DEA for supply chain performance evaluation. (Goedhals-Gerber, 2010) used the approach to measure the efficiency of supply chains in South Africa to determine if they can compete on the global market.

DEA and supply chain performance measurement

The following features of DEA make it increasingly attractive for supply chain performance measurements in face of the increasingly complex supply chains of the 21st century.

- It does not require prior knowledge of the interaction between the inputs and outputs (Peng Wong & Yew Wong, 2007; Shafiee, Lotfi, et al., 2014). This is suited for supply chain management where the inter-causal relationships between KPIs are complex and difficult to decipher.
- DEA works with multiple inputs and outputs where normal ratio analyses would fail (Charnes et al., 1978; Shafiee, Lotfi, et al., 2014). Supply chains have numerous inputs and outputs that are shared between the supply chain partners hence ratio analyses would not suffice in measuring efficiency.
- The weighting of inputs and outputs is not pre-determined (Shafiee, Lotfi, et al., 2014). This works well for supply chain where, due to the contestable importance of metrics relative to each other, subjective decision-making is likely to be high. It also assists with the potential problem of priority mismatch between supply chain partners.
- DEA uses an efficiency frontier, which is an appropriate empirical benchmark as opposed to theoretical benchmarks (Peng Wong & Yew Wong, 2007; Shafiee, Lotfi, et al., 2014).

DEA therefore offers potential solutions to some of the challenges associated with supply chain performance measurement. There is still, however, a number of challenges with DEA-based supply chain performance evaluation models. Being a linear programming approach, standard DEA assumes discrete inputs and output whereas supply chain performance measures exhibit some form and level of stochastic variations. Both Peng Wong and Yew Wong (2007) and Goedhals-Gerber (2010) identify the incorporation of the stochastic variations that characterise the supply chain environment into the DEA model for supply chain performance evaluation as a possible development area to enhance it.

2.5.5 *Proposition 2*

Data Envelopment Analysis can offer an alternative supply chain performance evaluation methodology that covers the entire chain and shows contributions of all the players to the overall performance of the chain.

2.6 Conclusion of Literature Review

The literature review has shown that in today's global business environment it is important for organisations to work more closely with their suppliers and customers in delivering goods and services to the end consumer (Halldorsson et al., 2007; Shi & Yu, 2013; Wu et al., 2014). Delivery of goods and services on time and in full to the customers and consumers is now a source of competitive advantage and the effectiveness and efficiency of the supply chain through various supply chain management best practices is critical in order to achieve that (Goedhals-Gerber, 2010). Therefore one of the main supply chain management objectives is to align and integrate supply chain partners' processes and many organisations are implementing supply chain integration best practices (Ramanathan & Gunasekaran, 2014). A number of factors however hamper supply chain integration among supply chain partners and prevent them from realising the potential benefits of integration (Ramanathan & Gunasekaran, 2014). One of these factors is the lack of aligned and effective supply chain measures and models that foster this integration.

A number of researchers like Kumar and Nambirajan (2013), MacBryde et al. (2006), Vaidya and Hudnurkar (2013) and Gunasekaran et al. (2015) have argued that existing supply chain performance measures and measurement frameworks lag behind the increasingly dynamic and global supply chains of the 21st century. They argue that existing methods and measures are internally focussed and encourage individualistic pursuit of internal performance targets at the expense of the performance of the entire supply chain. They have therefore advocated for new measures and models that support the integration philosophy of superior supply chain management. Key to the new requirements for these measures and models is the ability to measure the performance of the supply chain as a whole as well as the contribution of the supply chain players. Such measures will ensure the equitable sharing of rewards and penalties across the supply chain and hence bring the supply chain to work closer together.

Data Envelopment Analysis (DEA), a linear programming based method of measuring the efficiency of homogeneous Decision Making Units by Charnes et al. (1978) promises to offer a basis for an alternative to measure supply chain performance. Models based on DEA have been used in a number of case studies to evaluate supply chain performance but some gaps still remain in these models (Goedhals-Gerber, 2010; Peng Wong & Yew Wong, 2007; Tavana et al., 2013). The traditional DEA is a deterministic model, which works on discrete variables, therefore one such gap is the use of variables with stochastic variations (which better characterise the real supply chain environment and variables) on the DEA models. The linking of DMUs into a network – called network DEA, also represents supply chains better and promises better reliability in evaluating supply chain performance.

Based on the literature review the following proposition have been made and will be tested via a case study of the Vivo Energy lubricants supply chain:

Proposition 1: Supply chain performance measurement in the Vivo Energy lubricants supply chain is still fragmented across the supply chain and does not foster integration between the supply chain participants.

Proposition 2: Data Envelopment Analysis can offer an alternative supply chain performance evaluation methodology that covers the entire chain and shows contributions of all the players to the overall performance of the chain.

CHAPTER 3. RESEARCH METHODOLOGY

This study uses the mixed method approach to test the two propositions made. The first objective is to establish face validity to the proposition that existing supply chain performance measurement practices in the case study supply chain do not support integration. This is done through a qualitative approach of semi-structured interviews with key supply chain managers in the case study supply chain. The second objective is to quantitatively and objectively evaluate the case study supply chain's performance as well as the performance of the organisations within through the use of DEA. This way DEA is proposed as an alternative for evaluating supply chain performance in a way that achieves integration.

3.1 Research Methodology

This research takes the exploratory case study approach; testing the effectiveness of the existing supply chain performance measurement approach and then demonstrating the use of DEA as an alternative supply chain performance evaluation technique on the Vivo Energy lubricants supply chain. Yin (2013) states three criteria for determining the paradigm of a research – the type of question the research tries to answer, the degree of control exercised by the research on the behavioural events and the perspective and focus of the research between historical and contemporary events. This research is exploratory in nature; it proposes and tests the feasibility of measuring supply chain performance through an alternative DEA based methodology. The methodology is based on historical and contemporary supply chain performance data over which the research has no control. This, according to Yin (2013), is adequate basis to employ a case study approach.

Yin (2013) also defines a case study as an investigation that covers a contemporary phenomenon, which is context specific, works in situations where available data may be less than potential variables, relies on multiple sources of data and rides on prior theoretical framework. This research is specific to the Vivo Energy Lubricants business, its suppliers and its customers in each of the countries where they operate. The geographical scope is limited to the 16 countries in which Vivo Energy operates and those through which the physical supply chain covers.

Case studies have also been used by researchers to evaluate supply chain performance using DEA; Peng Wong and Yew Wong (2007) and Tavana et al. (2013) have both used case study supply chain to demonstrate the use of DEA to measure supply chain performance. Gopal and Thakkar (2012) in their insights on contemporary research on supply chain performance measures and metrics, also suggest empirical results of measures that are built on sound mathematical models and case studies.

3.2 Research Design

This case study attempts to validate the shortfalls of current supply chain performance methods against the objective of supply chain integration as established in the literature review. Semi-structured interviews were conducted with senior supply chain managers in the Vivo Energy lubricants supply chain in order to test the proposition that the current supply chain performance measurements models and metrics in the Vivo Energy lubricants supply chain are not adequate in fostering integration across the supply chain. The interviews covered the current supply chain measures used in the respective organisations, the level of integration between Vivo Energy, its suppliers and its customers, and the level of comprehension of the potential benefits associated with improvement in current supply chain measures.

Using the identified performance measures during the interviews, the Vivo Energy Lubricants business supply chain was used to demonstrate the use of the supply chain efficiency measure (via the use of a DEA model) as an additional building block in measuring and encouraging integration between supply chain partners. Supply chain performance data on both the Vivo Energy lubricants businesses and their supplier for 24 months was analysed to establish average performance levels and variations. DEA was then used to evaluate the efficiency of the supply chain partners.

The advantages of using the case study approach are as follows

- A case study achieves in-depth analysis of the phenomenon being investigated Yin (2013). This is suitable in the supply chain context where the complexity of the supply chain is increasing due to globalisation and hence in-depth analyses would potentially give insights into significant causal relationship between the different performance variables.
- A case study can be chosen deliberately, strategically and conveniently in order to exploit the opportunity of conducting a focused study on a typical and representative case while achieving purpose and simplicity (Saldaña, 2011). A supply chain like VE's comprises many organisations and may have unique and specific internal and external environmental factors. It can best be researched on through a case study because of the multiple entities already included in the single case study.
- Although the common argument against case studies is that results cannot be generalised (Yin, 2013), Saldaña (2011) argues that generalizability and transferability of case research outcomes are highly dependent on how logical and interpretively persuasive the researcher is. In other words the researcher can still draw some inferences to the broader population if sound logic is employed to build the argument. In this case, inferences can be made on the basis that the internal and external factors that impact performance of the VE lubricants supply chain are likely to be common to any other supply chain that operates on the African continent.

There are, however, some disadvantages associated with the case study approach, according to (Yin, 2013):

- The potential for subjectivity is high. Interviews of people working in the supply chain being evaluated have their opinions and biases, which potentially impact how they view the level of integration with other organisations in the chain.
- Since only one case study will be used the research could be vulnerable to being too unique and not sufficiently representative of any other supply chain. This would potentially impact the level of external validity of the research.
- New information maybe discovered during the research, which might change the direction of focus. For instance interviews might fail to validate the need for an alternative supply chain performance evaluation methodology.

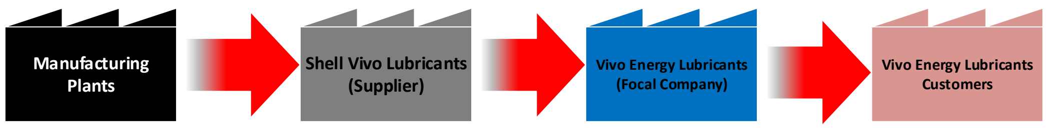
The Vivo Energy lubricants supply chain is a global supply chain. Products are sourced from both Europe and parts of the African continent and moved to the respective markets via the different modes of transport. The supply chain relies on the performance of both local and global supply chain players and infrastructure like shipping lines, ports, roads and government institutions. This makes it a typical supply chain that can be compared to any other supply chain in today's global business environment. Therefore the potential disadvantage of uniqueness can be mitigated.

3.3 Population and Sample

3.3.1 *Case: Vivo Energy lubricants*

The Vivo Energy lubricants supply chain in Africa was used as a case study for this research. Vivo Energy operates in 16 countries on the African continent and all these operations were used in the case study. All the Vivo Energy lubricants businesses in the 16 countries source their products from a number of manufacturing sites across the globe. However they source product through one company called Shell Vivo Lubricants (SVL), which is the designated sole supplier of lubricant products to Vivo Energy. Figure 10 shows the flow of product that represents the VE lubricants supply chain. So despite the products bought by VE entities coming from different parts of the world, VE entities interface with only one supplying entity – SVL. Therefore the main partners in the VE lubricants supply chain are SVL, VE and VE's customers.

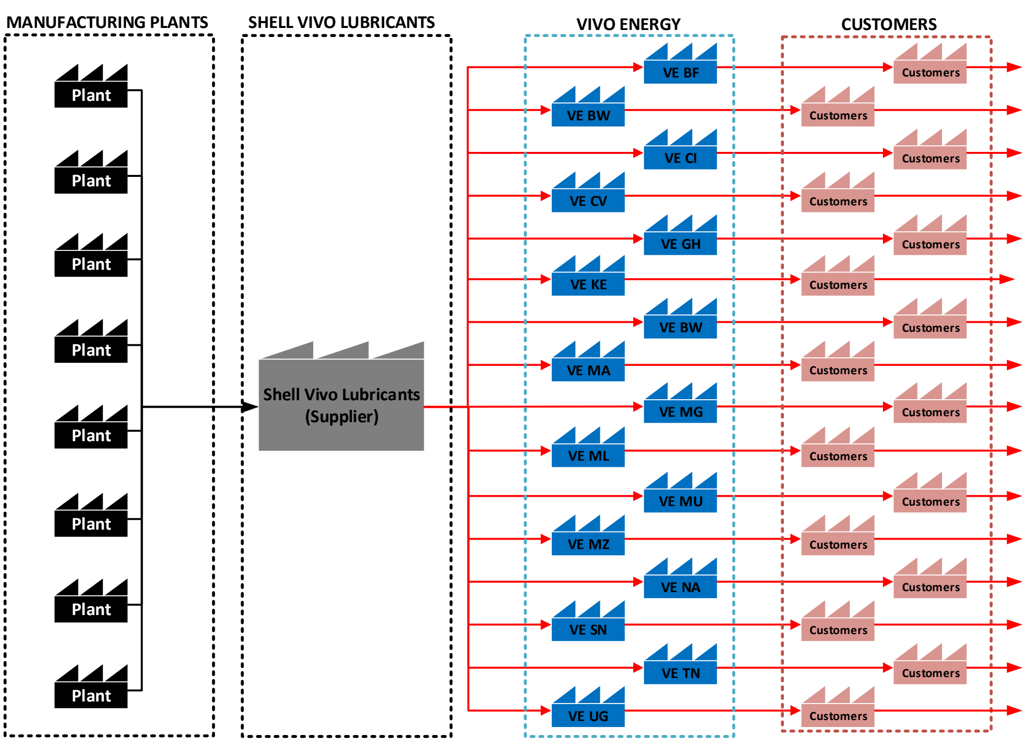
Figure 10: VE lubricants supply chain



Source: Own illustration

Exploding the VE business into the 16 businesses generates an extended supply chain shown in the Figure 11.

Figure 11: VE Lubricants' extended supply chain



Source: Own illustration

Some customers in the respective countries were chosen on the basis of size and availability of performance data.

3.3.2 *Sample and Sampling Method*

Semi-structured interviews were used to assess the validity of the first proposition; the interviews were targeted at individuals in the VE lubricants supply chain who interact with other organisations external to their own. In SVL, interviews were conducted with the people in the Operations function, which is responsible the Order-To-Cash (OTC) process. The SVL Operations function receives orders from all VE countries and in turn places orders with the designated manufacturing plants where product is sourced. They also oversee the availability of product, the timing of product availability, the loading and delivery to the customers. In VE, interviews were conducted with members of the Supply and Distribution function, which is responsible for the forecasting of product requirements, placement of orders with SVL and receipt of product into VE's warehouse facilities. The Supply and Distribution function is also responsible for the fulfilment of customer orders placed on VE by its customers. A member of the VE Central Management Accounting was also interviewed with specific emphasis on the costs associated with the supply of lubricants from SVL to the VE customers. At VE's customers interviews were conducted with the contacts responsible ordering product from VE.

Table 3: Profile of interview respondents

Organisation	Function	Number interviewed
Shell Vivo Lubricants (SVL)	Operations	3
Shell Vivo Lubricants (SVL)	Supply Chain	2
Vivo Energy	Supply and Distribution	21
Vivo Energy	Central Management Accounting	1
Vivo Energy customers	Supply	5

Real performance data from Vivo Energy's lubricants supply chain was collected and used to assess the supply chain efficiency of the supply chain using DEA. This was collected from performance reports and business information management systems of Vivo Energy and SVL.

3.4 Research Instruments

The research used questionnaires that were designed to address the aspects supply chain performance measurement and integration. The questionnaires are attached in Appendix A. DEA was performed using the DEA Solver version 3 software, provided as supporting material by Cooper et al. (2006).

3.5 Procedure for Data Collection

Semi-structured interviews were used to collect data on the level of integration and performance measures used to manage the supply chain. Through these interviews, the supply chain performance measures used by the supply chain partners were identified and aligned as much as possible with the variables used for the DEA process. This way some of the qualitative outputs of the interviews could be used to help with the interpretation and validation of the DEA results. Because this research relied heavily on DEA which is a mathematical model, its reliability and validity also relied on the accuracy of the data used as argued by Manzoni (2007). For that reason secondary data in the form of supply chain performance reports of each Vivo Energy business were requested from the relevant functions responsible for information management and reporting. Supply and Distribution functions in the VE businesses were sources of most of the performance data while Central Management Accounting supplemented with cost and margin related performance data. In cases where data was not readily available in the reports or scorecards, further calculations were done to determine the performance variables. For instance, although SVL's manufacturing lead-time is not tracked as a discrete performance indicator, it could be calculated from the order date and receipt date available in the Enterprise Resource Planning (ERP) system.

3.6 Data Analysis and Interpretation

The data collected from performance reports and other sources was analysed via Microsoft Excel to establish the statistical averages and variances where applicable. DEA Solver version 3 developed and offered as supporting material by Cooper et al. (2006) was used to perform the Data Envelopment Analysis.

3.6.1 *DEA Data Assumptions*

Inputs: The performance measures chosen to be inputs of the DMUs were selected based on the performance objective of the business behind these measures. Inputs were selected to be those performance measures that the business intended to minimize as much as possible in order to improve performance. Using that argument the SVL DMU's inputs were chosen as Oil Price, Oil stock days cover, Additives stock days cover and supplier lead-time. For the VE DMUs the inputs were chosen as SVL manufacturing lead-time, finished product stock days cover and the cost of the product.

Outputs: The performance measures that were chosen to be the outputs of the VE DMUs were selected based on maximization as the business's primary performance objective behind those performance measures. VE DMUs' outputs were therefore selected as On-Time-In-Full (OTIF) delivery, profit margin and sales volume. SVL's outputs were not selected on the maximization principle – they were selected to be direct inputs to VE (or be closely related to VE's inputs) in order to assess the level of optimization (or optimization potential) between the two businesses. Therefore SVL's outputs were selected as On-Tim-In-Full (OTIF) delivery (which determines, to some extent, the day's cover of stock of VE), the price of product (which is a big driver of cost of product for VE), and the manufacturing lead time (which is taken as a direct input into VE DMUs).

Orientation: Output-oriented DEA was used as the primary model to analyse the supply chain performance of SVL and VE businesses in the 16 countries. The choice of output-oriented DEA was made in line with the argument that both SVL and VE businesses have more control over the output performance variables than on their input performance variables which may depend on the supply chain operating environment or upstream supply chain partners. Therefore the primary objective for both of them is to improve and maximize their outputs first, on the basis of current input levels, before engaging with upstream supply chain partners for more favourable inputs.

Returns to Scale: In order to simplify the analysis it was assumed that all business entities being analysed still have potential for constant returns to scale. This was also decided because there was no information gathered, either through the interviews or otherwise, to suggest that some VE lubricant businesses have exceeded their optimal sizes.

Weights: Because of the complex interrelationships between the performance indicators chosen, no restrictions were imposed on the weights of the DEA model to avoid unintended biasing of outcomes. This would also potentially offer insights into the importance of the different performance measures to the different businesses in the analyses.

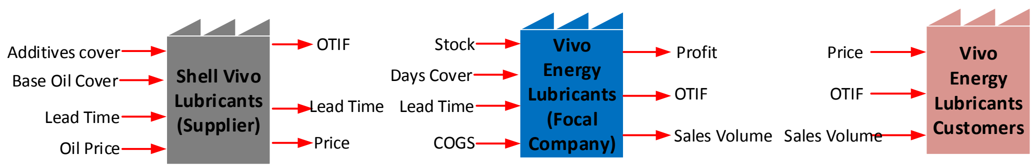
Prior Knowledge: No restrictions were imposed on the initial DEA models in order to avoid unnecessary bias on the initial results. Restrictions were only applied to some variables to show the incorporation of management insights and prior knowledge to the DEA methodology.

3.6.2 *DEA Model: VE lubricants supply chain*

As outlined in the DEA assumptions in 3.6.1, the DEA model for the VE lubricants supply chain is based on the inputs and outputs shown in Figure

12. Due to insufficient data on customer performance, VE customers were excluded from the DEA model; the maximization of VE outputs (sales volume and OTIF) were assumed to be aligned with the general performance objectives of customers. Maximization of profit would not necessarily breach customers' performance objectives as long as it is achieved through cost reduction in VE and not price increase.

Figure 12: DEA model inputs and outputs



Source: Own illustration

The first DEA was performance on the 16 VE DMUs based on their 2015 average performance; this will be referred to as the **Operating Unit (OU) DEA model**. This was done in order to establish the relative efficiency of each VE DMU and the benchmark DMUs. In order to satisfy one of the data requirements of DEA on number of inputs and outputs, as prescribed by Cooper et al. (2007), a minimum of 18 DMUs were required for a model comprising DMUs with 3 inputs and 3 outputs. (For the OU DEA model only three VE DMU inputs were used – days' cover, lead time and COGS). Therefore, additional two 'dummy' DMUs were introduced – one DMU based on the actual consolidated performance of VE lubricants and another one based on the consolidated VE lubricants targets of inputs and output performance measures.

After the UO DEA model of the 18 DMUs, DEA window analyses were performed on each VE business based on month-on-month performance over 24 months. This will be referred to as the **DEA window analysis model**. Window analyses were done in order to assess the variability of performance over the 2-year period. This would test the consistence of each DMU's performance over the period, especially the identified benchmark DMUs. Due to the underlying assumption taken that SVL would be represented by one

DMU, only the DEA window analysis was performed on the SVL DMU based on the 24 months' performance.

In order to check the consistency and stability (or lack thereof) of the efficiencies derived from the operating unit DEA model, sensitivity analyses were done. The first sensitivity analysis was done through imposing a restriction on the sales volume; maximum possible sales volumes were restricted to double the observed sales for all the operating units in the OU DEA model. In other words, the OU DEA model was re-run but with the new assumption that, in trying to maximize their efficiency, operating units could only increase their sales volumes to a maximum of double the demonstrated or observed volumes.

The second sensitivity analysis was done using the month-on-month performance measures of Morocco and Guinea (two of the three identified benchmarks in the OU DEA model). Using the actual month-on-month performance of these two units over 12 months from January 2015 to December 2015, 144 possible combinations of these two DMUs' performance were used together with the average performance of the other 14 DMUs to run 144 iterations of the OU DEA model. The resultant efficiencies for each unit for the 144 iterations showed the sensitivity of each DMU's efficiency to the changing efficiencies of Morocco and Kenya.

3.7 Limitations of the Study

The following are the potential limitations of the study:

- A case study cannot be generalizable statistically and therefore the results of the research cannot be inferred on the broader population of supply chains.
- There is potential bias and subjectivity in data gathering via interviews of people in the Vivo Energy supply chain.

- Due to the data requirements limitations of DEA only a limited number of performance variables could be used to characterize and model the supply chain and its performance. Therefore, the outcomes of the study are only valid in as far as those variables are used as the sole defining variables of the performance of the supply chain.

3.8 Validity and Reliability

3.8.1 *External Validity*

External validity for this case study points to how the results can be generalised on any other supply chain under similar external conditions. This research is a replication of similar studies done by, Peng Wong and Yew Wong (2007), Goedhals-Gerber (2010) and Tavana et al. (2013) but with variation in the stochastic characteristics of some of the variables. Analytical generalisation (as opposed to statistical generalisation) is the basis for claiming external validity in a case study that proves the application of a well-established theory (Yin, 2013). DEA is a well-established linear programming method developed by Charnes et al. (1978) and this case study seeks to validate its application in supply chain performance evaluation under conditions of uncertainty in some of the inputs and outputs which is typical of any supply chain.

While the case study output is not externally valid from a statistical perspective, the conditions and institutions that influence the performance behaviour of the Vivo Energy lubricants supply chain can be argued to be similar to any other typical supply chain on the African continent. For instance movement of products from Vivo Energy's suppliers is through shipping lines, ports and road and rail transport modes that are also in use in other supply chains on the continent. These have a significant bearing on the performance of Vivo Energy supply chain presumably in the same way they would impact another supply chain in Africa. On this basis a certain level of external validity can be established.

3.8.2 *Internal Validity*

Yin (2013) presents two potential threats to the internal validity of a case study – incorrect conclusion on the causal relationships between variables in the phenomenon under research and wrong inferences of events observed in the data collected. In this Vivo Energy lubricants supply chain case study internal validity will be centred on whether the result of this research accurately demonstrate the applicability (or otherwise) of DEA approach as a supply chain evaluation technique. This answers the question of whether the results of the efficiency analysis truly reflect the relative operational efficiencies of the organisational entities in the Vivo Energy lubricants supply chain. Alignment between the DEA results and the themes derived from the interviews is key in establishing internal validity.

3.8.3 *Reliability*

Reliability is defined as the minimal presence of bias and error in the procedure such that if another researcher follows the same procedure for the same study, similar results would be arrived at (Yin, 2013). Manzoni (2007) stresses the importance of data accuracy in a research based on mathematical models like this one. Therefore in order to ensure reliability, the gathering of supply chain performance data will be confined to formal reports and data from the enterprise resource systems of and other related systems. Data gathered via interview would be used to prove face validity of the proposition that existing measures and methodologies do not support integration in the supply chain and potentially help explain some of the results of the DEA model.

CHAPTER 4. PRESENTATION OF RESULTS

4.1 Introduction

In this chapter, the outcomes of the interviews and the DEA based evaluation of the VE lubricants supply chain are presented in line with the two propositions made from the literature review. A number of performance measures used to track the effectiveness and efficiency of the supply chain by SVL and VE are defined. The target setting approaches employed for these measures are also presented together with the actual performance against the targets. Collaborative activities taking between SVL, VE and customers, as well as issues hampering performance are discussed to assess the level of integration between SVL, VE and the final customers. The results of DEA-based supply chain performance evaluation of the VE lubricants supply chain are presented to demonstrate how DEA can be used to measure supply chain performance. Only selected DEA results out of the 16 supply chains are presented in this chapter in order to demonstrate the use of DEA; a similar approach can be used on the rest of the DEA results that are shown in the Appendices.

4.2 Results pertaining to Proposition 1

4.2.1 *Supply chain performance measurement*

Vivo Energy lubricants

The interviews with VE Supply and Distribution respondents established that the VE lubricants supply chain employs the following supply chain performance measures to evaluate performance against the goals of reliable supply of products on time in full to meet customer expectations. These measures are tracked by all the 16 countries, together with some lower level measures like distance covered each month by delivery trucks, number of drops made by these trucks, vehicle time and capacity utilisation.

- **On Time in Full (OTIF):** This is a percentage of the orders that are delivered within the tolerance of customers' requested date and quantity. The formula for calculating OTIF is as below:

$$Customer\ OTIF = \frac{No\ of\ Orders\ Delivered\ on\ Time\ in\ Full}{Total\ No\ of\ Order\ Placed\ by\ Customers} x100\%$$

- **Days on hand cover of stock:** this is a comparison of the total physical stocks of lubricants held by a Vivo Energy business at the end of the month against the actual total sales volume of the same month. The formula for calculating days cover is below:

$$Stock\ Days\ Cover = \frac{Quantity\ of\ Stock\ on\ Hand}{Sales\ Volume\ for\ the\ month} x\ 30\ days$$

  The days on hand cover of stock indicator shows, on average, how many days it takes to deplete the stock being held assuming sales remain constant at the previous month's level.

- **Cost of Goods Sold (COGS):** This is the cost of purchasing product and landing it into the VE warehouse ready for sale to customers. It is built up of the purchase price from SVL, the freight cost, duties and taxes and the in-country transportation cost of setting product to the final warehouse. COGS is reported per litre of products as calculated by the formula below:

$$Cost\ of\ Goods\ Sold\ (COGS) = \frac{Purchase\ Cost + Freight + Duties\ \&\ Taxes}{Quantity\ of\ product\ sold\ during\ the\ month}$$

  The Cost of Goods Sold is calculated on the basis of the stock sold during the month in review i.e. it is the cost associated with the stock that was sold (as opposed to stock that was received) during the month in review.

- **Transport cost:** The cost incurred to move product from the suppliers to the customer's requested delivery location. This cost is broken down into the different legs involved – primary transport from the supplier to the last warehouse and secondary transport from the last warehouse to the customer delivery location. This is reported per litre of product as in the formula below.

$$Transport\ Cost = \frac{Total\ Transport\ cost}{Quantity\ of\ product\ sold\ during\ the\ month}$$

- **Warehousing Cost:** cost incurred to store and handle product in the warehouses and is reported per litre as in the formula below.

$$Warehousing\ Costs = \frac{Total\ Warehousing\ Cost}{Quantity\ of\ product\ sold\ during\ the\ month}$$

- **Sales volume:** this is the quantity, in litres or cubic metres, of product that is sold in a particular month. This can be tracked as an absolute value or in comparison to a forecasted and planned quantity for that month as expressed by the formula below.

$$Sales\ vs.\ Plan = \frac{Actual\ Sales\ Volume}{Planned\ Sales\ Volume}\ x\ 100\%$$

- **Profit margins:** this is difference between the proceeds from the sale of product and the cost of achieving those sales. There are a number of profit margins reported depending on the level of the supply chain. The lowest profit margin that is of interest to supply chain managers in VE lubricants incorporates the total cost of delivering product to the customers and is given by the formula below;

$$Profit\ margin = Proceeds - \sum total\ cost\ of\ delivering\ to\ the\ customer$$

All VE respondents confirmed that they did not have any measures to directly assess the performance of the supplier SVL. The operational relationship between SVL and VE is governed by a legal agreement, which specifies the expectations of both parties in terms of supply chain operations. However, still, there are no discrete performance measures tracked to check SVL compliance with the agreement. Similarly there are no performance measures meant to directly assess the performance of VE customers. Performance of customers is generally assessed based on sales volume achieved by customer, which is jointly reviewed monthly by VE and customers.

Shell Vivo Lubricants (SVL)

Shell Vivo Lubricants (SVL), VE's sole supplier of lubricants, also tracks a number of performance indicators to evaluate their part of the supply chain. The following are some key performance indicators that they track:

- **On Time in Full (OTIF):** this is measured as the compliance to promised date and quantity of each order place by VE on SVL. Important to note is the point that the promise date is a date given by SVL after order placement and at times the quantity is changed to meet constraints in SVL's operations. The promise date also refers to the date promised for product to be available for pick up from the manufacturing facility.

$$OTIF = \frac{No\ of\ Orders\ Available\ \ in\ Full\ on\ Promised\ Date}{Total\ No\ of\ Order\ Placed\ by\ VE} x100\%$$

- **Days cover of stock:** this is the amount of raw materials held compared to the average monthly production requirements. This measure is tracked separately for the two key raw material groups – base oils and additives, used to produce lubricants.

$$Oil\ Stock\ Days\ Cover = \frac{Oil\ Stock\ on\ Hand}{Volume\ Required\ for\ the\ month's\ production} x\ 30\ days$$

$$Additives\ Stock\ Days\ Cover = \frac{Additives\ Stock\ on\ Hand}{Volume\ Required\ for\ the\ month's\ production} x\ 30\ days$$

Similar to VE, data extracted from the ERP systems gives more insights into the performance of the SVL supply chain.

SVL uses one measure to assess the performance of VE businesses. The performance measure is **forecast accuracy** of the orders placed by VE businesses. The forecast accuracy is measured as the variance between the actual quantities of product ordered versus what would have been forecasted two months prior to the month under consideration. The formula below captures how SVL calculate the forecast accuracy of VE.

$$Forecast\ Accuracy = [1 - \frac{Absolute(Actual\ - Forecast)}{Forecast}]\ x\ 100\%$$

VE's Customers

Interviews with customers established that the key performance measures they tracked are sales volume, amount of product in stock and the lead-time taken by VE to deliver orders. No customers were willing to share the details of how these measures are calculated, the actual performance against these measures or the targets for these measures.

4.2.2 *Performance target setting*

The targets for the performance indicators measured by VE are set every year. The approach employed for target setting is very de-centralized; each business / country sets its targets and communicates them to the central functions for consolidation with the rest of the other businesses. The factors that inform the new targets each year are not standard; discretion and the previous year's performance normally inform what the new targets are. There are no formal consultations with SVL on any targets set by VE businesses.

In SVL, targets are set every year on the basis of the previous year's performance and some degree of management's discretion. There is very minimal consultation with the VE business on setting targets even for those measures directed towards VE. For instance SVL indicated that the forecast accuracy target imposed on VE countries by SVL was derived from analyses by SVL with limited to no input at all from VE countries.

4.2.3 *Collaboration between VE and supplier*

Despite being sister businesses with the same shareholders, there are very limited joint activities between VE and SVL in the strategic planning and execution of the lubricants supply chain. Apart from the board meetings of the two business entities and the sharing of expected annual volume sales by VE businesses, there are very few forums where the extended supply chain is reviewed collectively and collaboratively by the two businesses. Review meetings that happen on a monthly basis discuss contemporary operational problems around orders that will be in the pipeline at that time.

The following were cited by both VE and SVL as the main issues that hindered the smooth operation of the supply:

Shell Vivo Lubricants

- Poor forecast accuracy by VE on orders placed to SVL, which results in overstocks in raw materials or out-of-stock situations on some products.
- Late payments for order by VE after delivery.
- Changes to orders within frozen horizon of the planning timelines. This
- Late pick up of orders after manufacturing is complete.

Vivo Energy

- Long lead times from order placement to when orders are ready to pick.
- Variability of lead time; lead times are not predictable and hence sometimes orders are ready too early and too late at other time
- Incomplete shipping documents that delay the clearance of orders upon arrival in the destination countries.
- Forced order changes due to constraints in the SVL manufacturing sites. Constraints cited were inadequate raw materials

4.2.4 *Collaboration between VE and customers*

The interaction between VE and its major customers is mainly driven by the sales function in VE. Business review meetings are the main form of interaction and these review sales volumes and any other issues like pricing, supply and economic environmental factors that might impact the achievement of sales targets for the customers.

The following were cited by both VE and customers interviewed as the main issues that hindered the smooth operation of the supply:

Vivo Energy

- Late changes to orders by customers after placement of order with SVL.
- Poor forecast accuracy by customers of their requirements

Customers

- Poor compliance to requested delivery date and order quantities.
- Long lead time between order placement date and receipt date
- Lead-time variability – lead-time varies between orders and hence becomes unpredictable.
- Unavailability of new products that customers want to order.

4.2.5 *Actual Performance*

Views on actual performance were varied across VE and SVL; generally VE interviewees were not satisfied with the performance of the lubricants supply chain, citing poor performance against the key performance indicators. Poor performance was largely blamed on poor supply reliability of product from SVL. All VE interviewees expressed their wish to see improvement by SVL on lead-time and delivery performance on time and in full against orders. On the contrary SVL interviewees were more positive about the performance of their part of the supply chain; citing good delivery performance against promised date to VE entities. Top of the issues expressed by SVL as key priorities for VE to improve was the forecast accuracy.

4.2.6 *Summary of Interview Results*

The interviews showed that there is a standard list of key performance indicators that is employed by all VE businesses to track the performance of the supply chain. SVL also tracks similar performance indicators to track the performance of the supply chain from their perspective. Management in each of the entities concerned primarily sets the targets for these performance indicators internally; there is minimal consultation between the entities when setting performance targets. Performance against the latest targets is mixed, with some operating units meeting some targets and some failing to meet some targets. A number of issues are clearly hampering the smooth operation of the supply chain and each player in the chain was quick to pick areas of improvement for the other players.

4.3 Results pertaining to Proposition 2

4.3.1 *Operating units DEA*

The 2015 performance of VE lubricants businesses against the selected measures for the OU DEA model is shown in Table 4. This performance data was also used for the OU DEA model.

Table 4: VE Businesses' supply chain performance

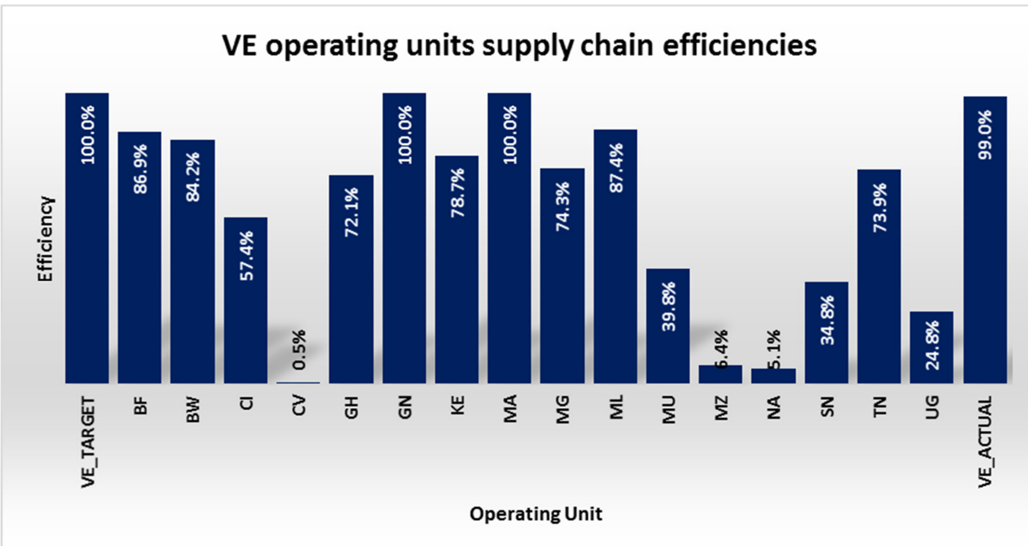
OPERATING UNIT	DAYS ON HAND (DAYS)	PURCHASE COST ($/L)	LEAD TIME (DAYS)	OTIF (%)	SALES VOLUME ('000M^3)	PROFIT MARGIN ($/L)
VE TARGET (VT)	85.0	1.9	30	93.0%	6.56	0.6
BURKINA FASO (BF)	132.1	4.0	47	87.2%	0.19	1.2
BOTSWANA (BW)	104.0	2.1	41	88.5%	0.05	0.9
IVORY COAST (CI)	125.7	2.0	37	86.9%	0.29	0.5
CAPE VERDE (CV)	282.5	2.5	39	99.4%	0.04	0.0
GHANA (GH)	80.2	1.9	39	67.8%	0.65	0.6
GUINEA (GN)	109.2	2.3	34	80.5%	0.23	1.1

KENYA (KE)	38.6	0.9	37	92.3%	1.10	0.3
MOROCCO (MA)	17.3	1.8	29	77.2%	0.94	0.7
MADAGASCAR (MG)	249.6	1.9	38	93.5%	0.13	0.7
MALI (ML)	100.9	2.1	43	96.4%	0.44	0.9
MAURITIUS (MU)	143.1	2.3	38	85.0%	0.16	0.4
MOZAMBIQUE (MZ)	186.1	2.1	52	80.7%	0.22	0.1
NAMIBIA (NA)	279.0	1.8	39	79.8%	0.13	0.0
SENEGAL (SN)	96.1	2.3	47	97.3%	0.34	0.4
TUNISIA (TN)	37.9	1.5	35	47.8%	0.70	0.5
UGANDA (UG)	65.6	2.4	46	79.9%	0.36	0.2
VE ACTUAL (VA)	78.1	2.1	38	79.1%	5.97	0.5

Source: VE Performance Reports (2015)

The results of OU DEA model are shown in Figure 13. The VE operating units with 100% efficiency are Morocco, Guinea and the consolidated VE targets DMU. All the other DMUs exhibit efficiencies between 100% and the lowest efficiency of 0.5% (for Cape Verde).

Figure 13: VE Operating Units supply chain efficiencies



Benchmark operating units

Table 5 shows the DEA-identified benchmark operating units for each of the operating unit that is not operating at 100% efficiency. The aggregate VE target (VT) appears as a benchmark all ‘inefficient’ units except Burkina Faso

(BF) and Botswana (BW). It is also notable that the benchmark unit for VE is the VE target (VT) DMU.

Table 5: Benchmark operating units

DMU	VT	BF	BW	CI	CV	GH	GN	KE	MA	MG	ML	MU	MZ	NA	SN	TN	UG	VE
Bench marks	**VT**	GN	GN	VT	VT	VT	GN	VT	MA	VT	VT	VT	VT	VT	VT	VT	VT	VT
		MA		GN	VA	GN		GN			GN	GN	GN	GN	GN	GN	GN	
						MA		MA							MA	MA	MA	

Output shortages and input excesses

Table 6 shows the output shortages and input excesses associated with each operating unit that is inefficient. Output shortfalls are recorded for all operating units that are inefficient while input excesses are recorded for some (but not all) of the inefficient units.

Table 6: VE operating unit output shortfalls and input excesses

DMU	Efficiency	Excess DOH	Excess COGS	Excess LT	Shortage OTIF	Shortage SALES	Shortage PROFIT
VE TARGET	100.0%	-	-	-	-	-	-
BF	86.9%	-	-1.06	-5	12.8%	0.1	0.18
BW	84.2%	-6	-	-10	-16.2%	0.2	0.16
CI	57.4%	-33	-	-8	-17.1%	0.2	0.40
CV	0.6%	-188	-0.19	-	0.6%	7.2	0.66
GH	72.1%	-	-	-11	1.6%	0.3	0.24
GN	100.0%	-	-	-	-	-	-
KE	78.7%	-	-	-23	-54.7%	0.3	0.08
MA	100.0%	-	-	-	-	-	-
MG	74.3%	-161	-	-10	-28.1%	0.1	0.24
ML	87.4%	-5	-	-13	-24.2%	0.1	0.12
MU	39.8%	-38	-	-5	-6.8%	0.2	0.65
MZ	6.5%	-91	-	-20	4.8%	3.2	0.79
NA	5.1%	-196	-	-12	-7.3%	2.4	0.72
SN	34.8%	-	-	-13	-12.5%	0.6	0.69
TN	73.9%	-	-	-11	13.0%	0.2	0.16
UG	24.8%	-	-	-8	16.5%	1.1	0.75
VE ACTUAL	99.0%	-	-0.35	-10	6.3%	0.1	0.03

4.3.2 *Window analysis*

The performance of SVL over 24 months starting in January 2014 is shown in Table 7 and is used for the window analysis.

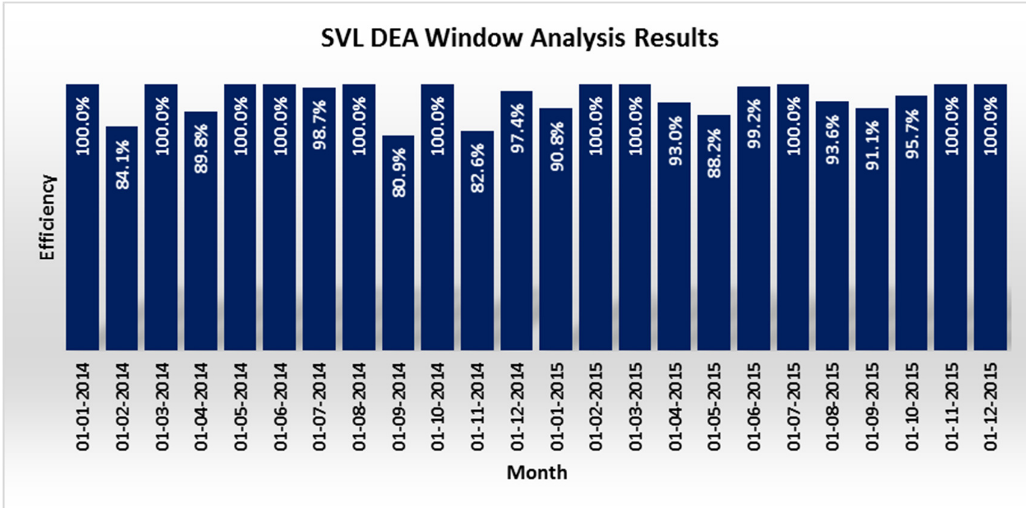
Table 7: SVL's supply chain performance data

Month	Oil Price ($/L)	Supplier Lead Time (Days)	Additives Days Cover (Days)	Oil Days Cover (Days)	Manufacturing Lead Time (Days)	Price ($/L)	OTIF (%)
Target	N/A	120.0	110.0	110.0	30	N/A	90.0%
Jan-14	1.06	136.0	73.2	104.4	49	1.84	85.0%
Feb-14	1.06	128.0	91.2	99.6	38	1.77	80.0%
Mar-14	1.07	110.0	90.0	90.0	41	1.72	72.0%
Apr-14	1.13	118.0	117.6	90.0	41	1.87	71.0%
May-14	1.15	101.0	114.0	138.0	45	1.72	87.0%
Jun-14	1.15	104.0	67.2	146.4	45	2.02	77.0%
Jul-14	1.14	109.0	112.8	84.0	51	1.99	88.0%
Aug-14	1.14	119.0	126.0	80.4	37	1.76	89.0%
Sep-14	1.11	117.0	127.2	109.2	42	1.66	88.0%
Oct-14	1.03	105.0	129.6	147.6	44	2.18	86.0%
Nov-14	0.93	115.0	123.6	103.2	36	1.87	87.0%
Dec-14	0.87	120.0	110.4	104.4	46	1.98	80.0%
Jan-15	0.78	113.0	109.2	85.2	39	1.64	87.0%
Feb-15	0.67	105.0	74.4	76.8	43	2.04	82.0%
Mar-15	0.69	113.0	54.0	92.4	34	1.68	91.0%
Apr-15	0.78	125.0	99.6	82.8	34	1.81	93.0%
May-15	0.81	121.0	102.0	105.6	42	1.83	95.0%
Jun-15	0.80	111.0	63.6	114.0	50	1.74	98.0%
Jul-15	0.77	116.0	121.2	140.4	38	2.74	97.0%
Aug-15	0.75	107.0	98.4	146.4	38	2.06	97.0%
Sep-15	0.70	102.0	80.4	151.2	35	1.27	99.0%
Oct-15	0.65	139.0	135.6	150.0	37	2.08	95.0%
Nov-15	0.63	137.0	122.4	147.6	42	1.68	95.0%
Dec-15	0.60	119.0	104.4	116.4	40	1.84	90.0%

Source: SVL Performance Reports

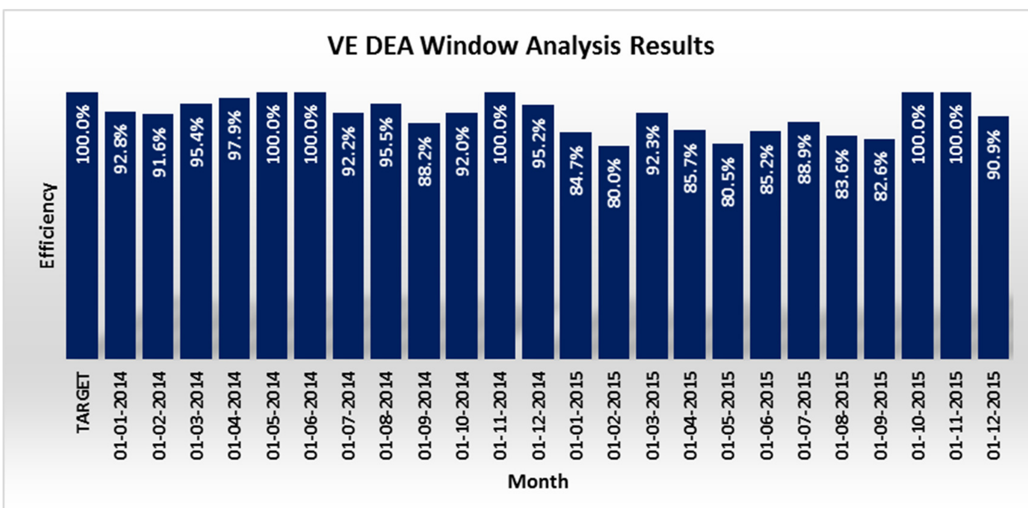
Figure 14 shows the window analysis of SVL over the 24 months, with 10 months out of the 24 showing 100% efficiency.

Figure 14: SVL window analysis results



The month-on-month performance data of the VE operating units that was used for the window analyses is in Appendix B. VE window analysis, in Figure 15, shows that 100% efficiency was achieved in 5 of the 24 months with most of these months falling in 2014 than in 2015.

Figure 15: VE window analysis results

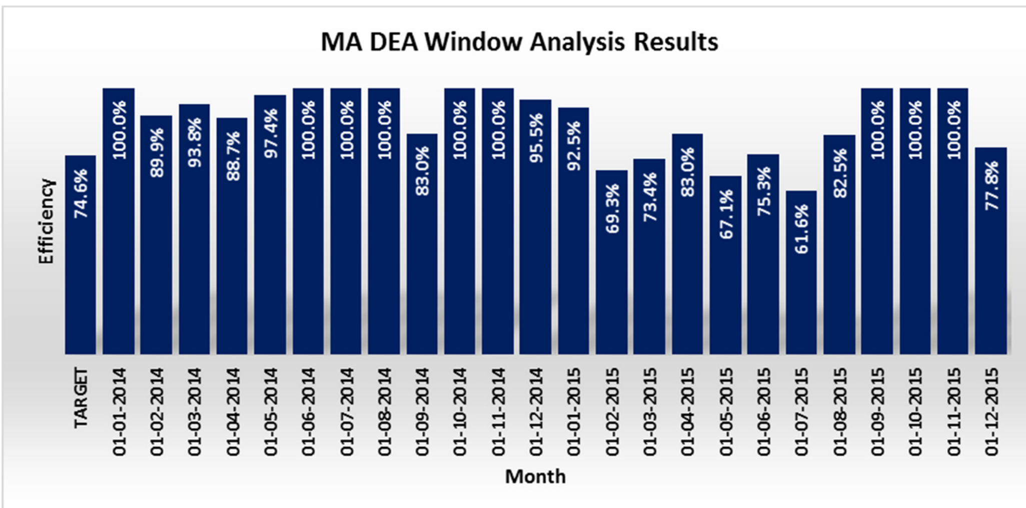


The results of 3 operating units are shown in the figures that follow. The three units are deliberately chosen as Guinea and Morocco (because they demonstrate 100% efficiency in the operating unit DEA model) and

Mozambique (because it demonstrates one of the lowest efficiencies in the operating unit DEA model).

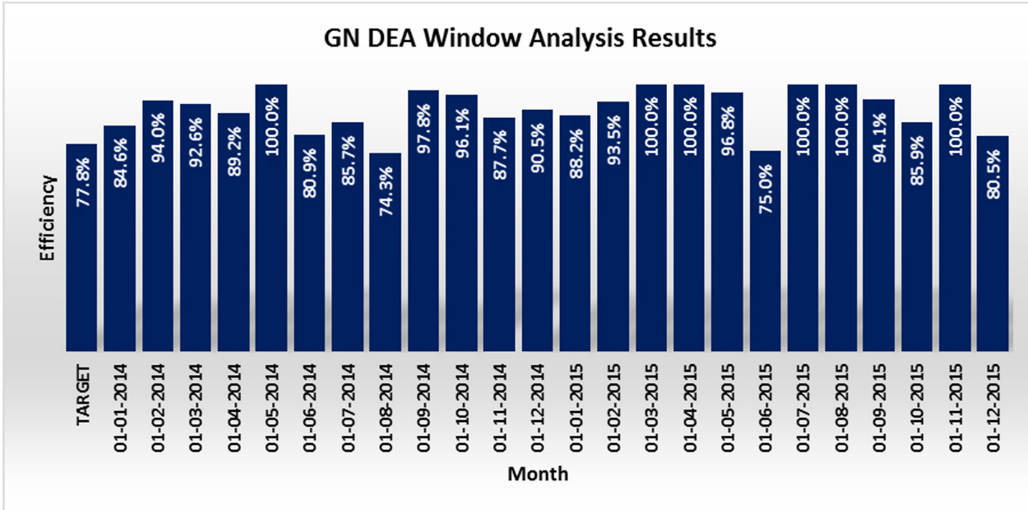
The results of the window analysis of Morocco are shown in Figure 16. It is notable that the targets of Morocco are associated with a 74.6% supply chain efficiency score. Morocco demonstrates 100% efficiency in 9 months out of the 24 months under consideration. Among these months with 100% efficiency are September 2015, October 2015 and November 2015. The lowest efficiency of 61.6% is seen in July 2015, followed by 67.1% in May 2015.

Figure 16: Morocco window analysis results



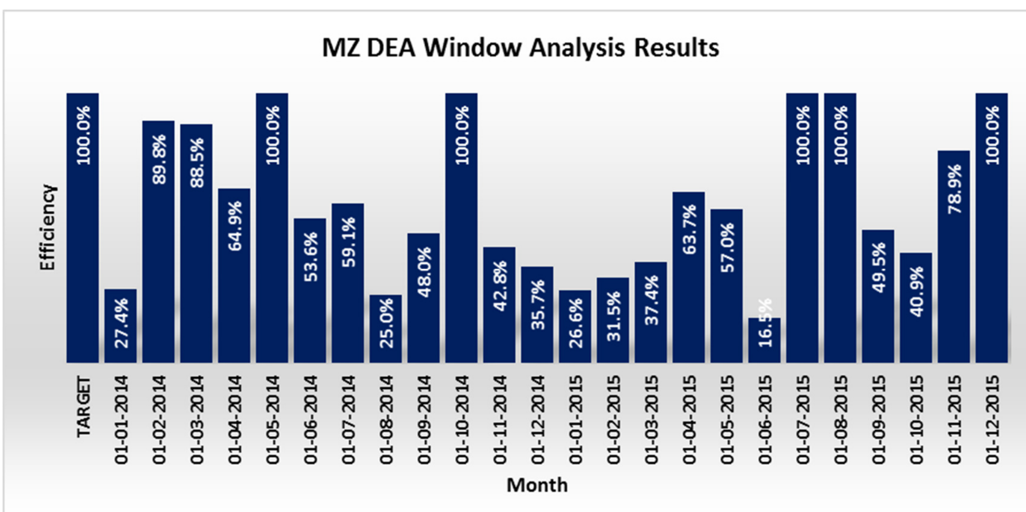
The results of the window analysis of Guinea are shown in Figure 17. Also notable is the 77.8% efficiency associated with the performance targets of Guinea. 6 months (May 2014, March, April, July, August and November of 2015) show 100% efficiency while the lowest efficiency of 74.3% is seen in August 2014 followed by 75.0% in June 2015.

Figure 17: Guinea window analysis results



Mozambique's window analysis results are shown in Figure 18. Performance targets for Mozambique give 100% efficiency together with actual performance in 5 other months (June and October of 2014, and July, August and December of 2015). The lowest efficiency of 16.5% is seen in June 2015 followed by 25.0% in August 2014.

Figure 18: Mozambique window analysis results

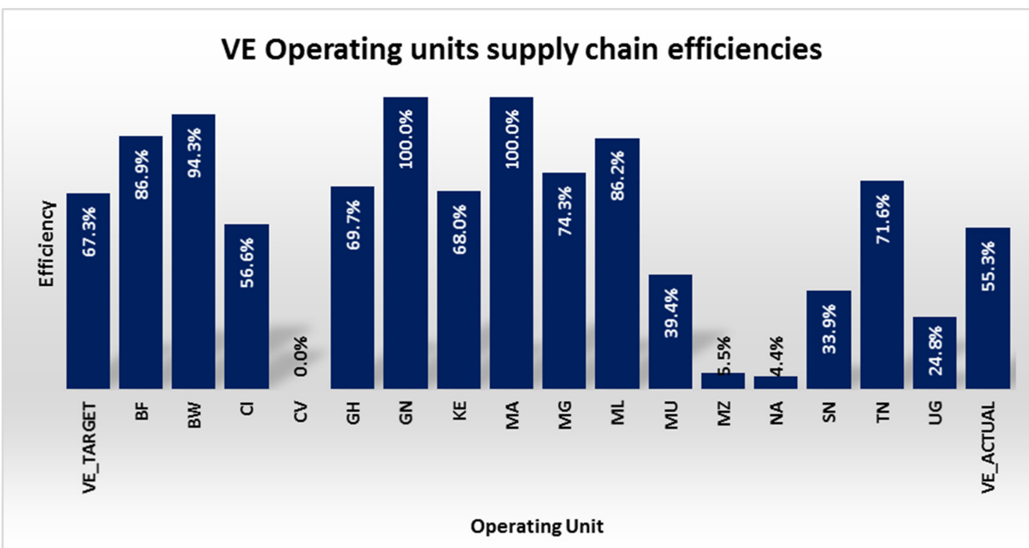


The results of the window analyses of all the other operating units are presented in Appendix C

4.3.3 *Sensitivity Analysis Results*

The first sensitivity analysis results, shown in Figure 19, show the OU DEA model output when sales volumes are restricted to double the observed values in 2015. Notable changes in the OU DEA model output (compared to output shown in Figure 13) is that 12 DMUs' efficiencies drop, including the DMU representing the consolidated VE targets which drops from 100% to 67.3%. The efficiency of the VE actual consolidated performance also drops from 99.0% to 55.3%. Morocco and Guinea remain unchanged at 100% together with Burkina Faso and Madagascar whose efficiencies remain unchanged. Botswana is the only operating unit whose efficiency improves due to the restriction.

Figure 19: VE operating units supply chain efficiencies with restriction on sales volumes



Source: Own illustration

The associated peer-benchmark pairings are shown in Table 8. Restricting sales volumes result on Guinea being a benchmark unit for all other units except Morocco and Cape Verde.

Table 8: Benchmark operating units with restriction on sales volumes

DMU	VT	BF	BW	CI	CV	GH	GN	KE	MA	MG	ML	MU	MZ	NA	SN	TN	UG	VE
Bench marks	GN	GN	BW	GN		GN	GN	GN	MA	GN	GN	GN	GN	GN	GN	GN	GN	GN
	MA	MA	GN			MA		MA							MA	MA	MA	MA

Source: Own illustration

The input excesses and output shortfalls are shown in Table 9. No major changes are seen in the input excesses except the immergence of excesses against the VE targets and consolidated actual performance DMUs. There are, however, significant changes in the output shortfalls as efficiency maximization responds to the restriction on sales volume. The most notable change is the negative and positive shortfalls on sales volume.

Table 9: Operating unit output shortfalls and input excesses with restriction on sales volumes

DMU	Efficiency	Excess DOH	Excess COGS	Excess LT	Shortage OTIF	Shortage SALES	Shortage PROFIT
VE TARGET	67.3%	-	-	-3	-27.91%	-6.3	0.29
BF	86.9%	-	-1.06	-5	12.82%	0.1	0.18
BW	94.3%	-2	-	-3	-5.23%	0.1	0.05
CI	56.6%	-33	-	-8	-18.48%	-0.1	0.42
CV	0.0%						
GH	69.7%	-	-	-12	-1.22%	-0.4	0.27
GN	100.0%	-	-	-	-	-	-
KE	68.0%	-	-	-23	-60.23%	-1.0	0.14
MA	100.0%	-	-	-	-	-	-
MG	74.3%	-161	-	-10	-28.12%	0.1	0.24
ML	86.2%	-5	-	-13	-25.57%	-0.2	0.14
MU	39.4%	-38	-	-6	-7.58%	0.1	0.66
MZ	5.5%	-90	-	-22	-9.66%	-0.0	0.95
NA	4.4%	-195	-	-13	-17.76%	0.1	0.83
SN	33.9%	-	-	-13	-15.18%	0.0	0.72
TN	71.6%	-	-	-12	11.09%	-0.2	0.18
UG	24.8%	-	-0.08	-10	9.89%	0.4	0.75
VE ACTUAL	55.3%	-	-	-6	-2.91%	-5.5	0.43

Source: Own illustration

The second set of sensitivity analyses show the variation of the efficiencies of the all the operating units as the efficiencies of the benchmark units (Guinea and Morocco in this case) vary. Using the observed month-on-month performance of Morocco and Guinea over the 12 months in 2015, 144 permutations of the OU DEA model were performed. The results of 3 units – Tunisia, Morocco and Guinea are shown and described while the rest of the units' results are in the Appendices.

Figure 20 shows the variation of Tunisia's efficiency as the efficiencies of Morocco and Guinea (benchmark units) are varied according to demonstrated window analyses efficiencies over the12-month period from January 2015 to December 2015.

Figure 20: Sensitivity analysis of Tunisia efficiency

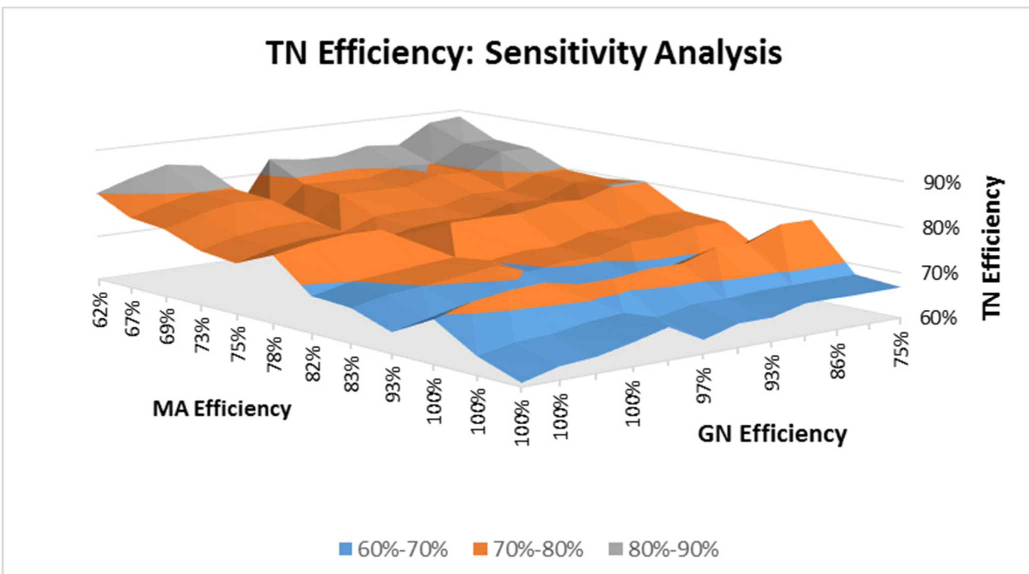


Figure 21 shows the sensitivity of the efficiency of Guinea, derived from the operating units DEA model.

Figure 21: Sensitivity analysis of Guinea efficiency

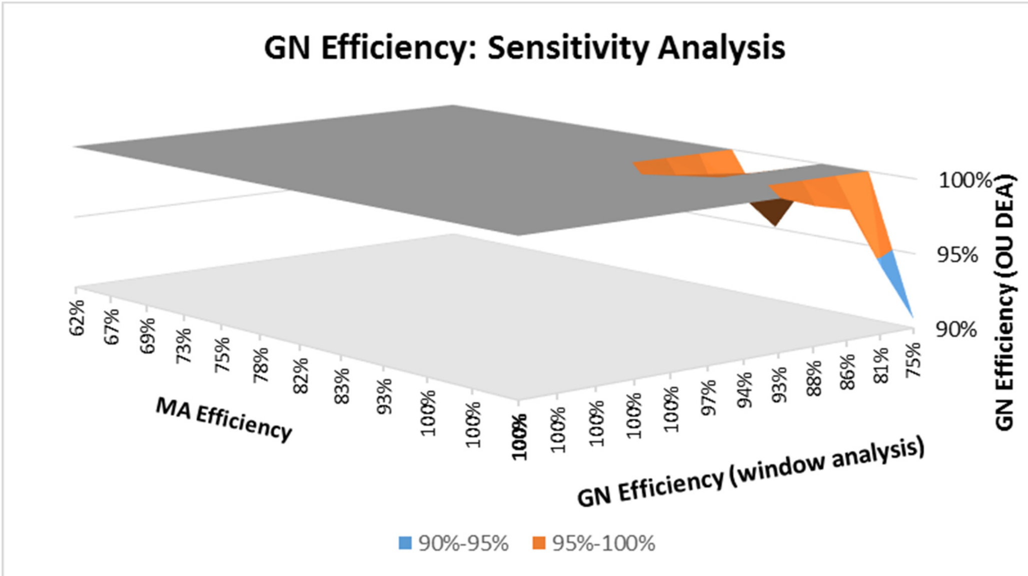
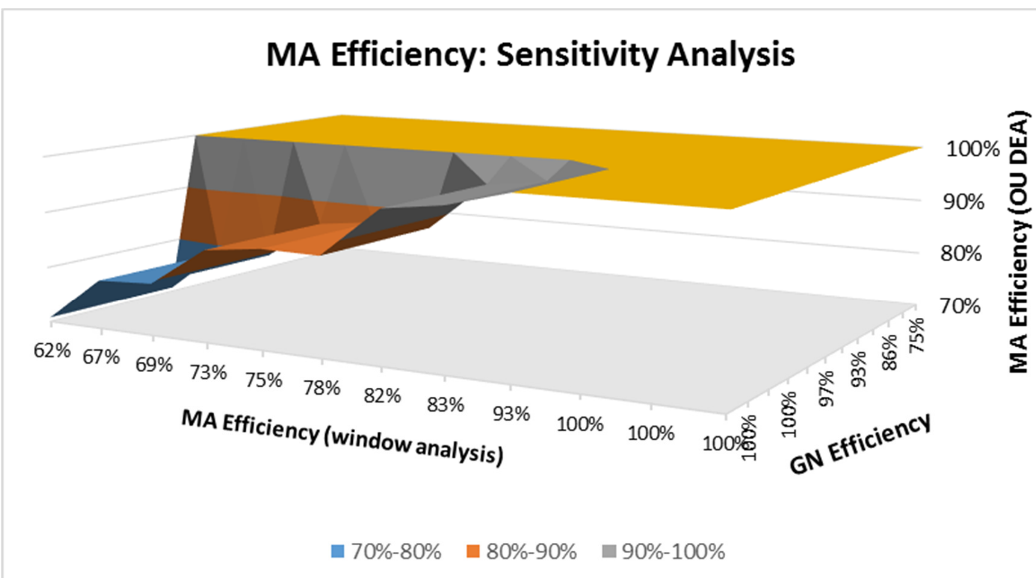


Figure 22 shows the results of the sensitivity analysis on Morocco's efficiency.

Figure 22: Sensitivity analysis of Morocco efficiency



All the other operating units' sensitivity analyses results are shown in Appendix D.

4.3.4 *Summary of DEA Results*

The results of the DEA models demonstrate how this methodology can be used to evaluate supply chain performance. The operating unit DEA model benchmarks operating units against each other and identified the benchmark units. This model also quantified the excesses and shortfalls in performance that each inefficient unit needs to shed or gain in order to utilise resources efficiently. Window analysis identified, for each unit, the months that it operated at maximum demonstrated efficiency as well as the poorest month in terms of efficiency. The sensitivity analysis showed the variation of efficiency for operating units as the efficiencies of the benchmark units changed.

4.4 Summary of the results

VE and SVL employ a number of performance measures to track the performance of the supply chain. The two common measures between SVL and VE are OTIF and day's cover of stock, and both are meant to assess the reliability of the supply chain in delivering products as per customers' expectation. Cost related measures like transport cost and warehousing cost are also tracked to measure the cost of delivering product. Collaboration between SVL and VE happens in form of review meetings meant to resolve operational issues impacting orders in the pipeline. Business reviews happening between VE and its customers are the only notable collaborative activity in the downstream part of the supply chain.

The DEA based performance evaluation identifies Morocco and Guinea as the operating units operating at 100% while Cape Verde is the least efficient operating unit at 0.5%. The window analyses show that there is month-on-month variation in the efficiency of each operating unit of the 24-month period from January 2014 to December 2015. The restriction of potential sales volumes results in some operating units' efficiencies declining, some remaining unchanged while others improve. The second set of sensitivity analyses on the efficiencies of the operating units show that there is some correlation between the efficiency of an operating unit and the efficiency of Guinea and Morocco.

CHAPTER 5. DISCUSSION OF THE RESULTS

5.1 Introduction

This chapter presents the assessment of the effectiveness of performance measurement in the VE lubricants supply chain, as gathered during the interviews, and discusses the insights from the results of DEA based performance evaluation of the VE lubricants supply chain. Firstly, the performance measurement system is evaluated based on the generic attributes of a good performance measurement system cited in the literature review. The evaluation is taken further and more specific to the attributes of an effective and efficient supply chain performance measurement system, based on how well it addresses the extended nature of the supply chain and fosters integration between the supply chain partners. The identified barriers to integration in the VE Lubricants supply chain are discussed together with the positives that can form the foundations of an effective measurement approach. The results of a DEA based measurement approach on the case study supply chain are discussed, also with reference to how DEA addresses the requisites of effective supply chain measurement.

5.2 Discussion pertaining to Proposition 1

5.2.1 *Performance measurement in VE lubricants*

The assessment of the effectiveness of performance measurement across VE lubricants supply chain is done by evaluating whether it enables the businesses involved to maximize their potential as argued by Gunasekaran and Kobu (2007). In line with Gunasekaran and Kobu (2007), Bhagwat and Sharma (2007) and Goedhals-Gerber (2010)'s attributes of a good performance management system the following questions are used to assess the case study's performance measurement approach.

Does performance measurement in VE lubricants enable sound decision-making by giving facts as opposed to subjective information?

All the performance measures identified in VE and SVL (OTIF, profit margin, sales volumes, stocks and days cover of stocks) are quantitative and hence would provide management with facts that enable them to make good decisions about the supply chain and the business at large. The underlying assumption of this assertion is that these measures are calculated and reported accurately as defined by VE and SVL.

Does performance measurement in VE lubricants assess performance against the strategic objectives?

Vivo Energy's vision is to become Africa's most respected energy business; the strategic objectives behind this vision are constant and reliable supply of products, on time and in full delivery against customer requirements and competitive cost of doing business (Vivo Energy, 2015). The list of performance indicators that are tracked can be identified together with the strategic objectives. OTIF is a very important measure that is tracked by all Vivo Energy business and it gives a good measure of consistent and reliable supply of products on time and in full to meet customer requirements. A number of measures associated with the cost of operating the supply chain and delivering product are also measured – transport costs, COGS, which target to manage and control costs. SVL, being the nominated sole supplier of VE has the mandate of ensuring that VE's vision and objectives are achieved. SVL's main objective is to ensure availability of product to VE at competitive cost. Availability of products seems to be well addressed by measure of OTIF while the cost related measures (operating costs, oil prices) address the cost.

Is performance measurement in VE lubricants capable of diagnosing performance issues and problem areas for correction and improvement?

The SCOR model, developed by the APICS Supply Chain Council, gives a good approach of diagnosing performance issues through a hierarchy of supply chain performance measures. The level-1 measures are called strategic metrics and are decomposed into level-2 measures, which can be used to diagnose performance gaps seen in the level-1 metrics (APICS Supply Chain Council, 2015). Similarly the level-2 metrics are decomposed into level-3 metrics. This way level-2 and level-3 metrics can be used to do a detailed root cause analysis.

In the case of Vivo Energy, there is limited decomposition of performance measures into lower level measures and therefore robust root cause identification may be difficult via the use of these measures. OTIF, for instance, has no supporting lower level diagnostic measures that can assist to understand the root causes of failing to meet customer order requirements. In cases where poor OTIF was recorded in the operating units, supply chain managers could hardly pinpoint in specific terms what the root causes were. A list of potential root causes was given – poor supply reliability of SVL, inaccurate capturing of orders in the system, order request date changes by customers but there were no lower level measures to give granular details of the contribution of each of these root causes to the overall loss of OTIF. One can assume that the this lack of proper root cause identification could be part of the reason for the OTIF not showing improvement between 2014 and 2015; it actually dropped from 82% in 2014 to 79% in 2015.

The lack of lower level measures could also be seen in the SVL performance measures. Questions on the causes of poor OTIF could not be sufficiently answered, especially on months in the past when root causes could not be remembered.

Does performance measurement identify performance gaps against best practices and benchmarks?

In both VE and SVL, the only benchmarks used in performance measurement are the targets against which measures are assessed – each performance measure has a target for the year. However when one considers that the respective management teams of each business primarily set most of these targets internally, it becomes debatable whether such targets are the appropriate benchmarks. Benchmarks in form of internally drafted targets may also fail the test of universal acceptance that supposedly goes with robust benchmarks and best practices.

Does performance measurement give motivation and justification for continuous improvement efforts?

One source of motivation for improvement in a performance measurement system is the setting of realistic, achievable and stretching targets. Stretching targets offer the right challenge that drives management to chase and try to achieve them. Achievable targets provide the satisfaction that comes from meeting the targets and presumably also provide a renewed hunger to pursue further targets. If targets are not achievable, one can argue that they offer neither an appropriate challenge to management nor any satisfaction at the end of the day. In some cases VE targets seem unrealistic and unachievable. For example the OTIF target for all countries was 93% while actual performance was below 82% for 2014 and 79% for 2015. In other cases targets are unrealistic because they are too generous, for instance the days cover target for Ghana (110 days), which was exceeded for 19 months out of the 24 months from January 2014 to December 2015. To compound this, the target was not reviewed in 2015 despite it having been easily exceeded in 2014. Uganda and Guinea are also examples showing this disparity between the days cover target and the actual performance – targets were maintained at 120 days (Guinea) and 75 days (Uganda) despite performance exceeding these targets in most of the months.

5.2.2 *Supply chain performance Measurement in VE lubricants*

The effectiveness and efficiency of a supply chain performance measurement regime is rooted in its ability to cater for the extended nature of the supply chain – incorporating other supply chain players like suppliers, distributors and affiliates (Khare, Saxsena, & Teewari, 2012). Therefore the evaluation of the case study supply chain performance measurement regime is based on how it answers the following questions related to integration and collaboration as argued by a number of scholars.

Does it drive the optimization of the entire supply chain as opposed to individual parts?

Vaidya & Hudnurkar (2013) define one attribute of an effective supply chain measurement system as having the ability to assess the extended supply chain as a whole and avoid focusing on parts of the supply at the expense of the whole chain. In this regard, the attempt to manage the whole supply chain between SVL and VE can be seen through the performance reviews that are conducted between the two entities. These reviews are meant to ensure both organisations can achieve their targets without compromising each other's performance so in that regard the performance systems tries to ensure that the entire supply chain is optimized. There is however not enough evidence of other collaborative activities, beyond the review meetings, between SVL and VE in the supply chain to attempt to optimize the supply chain. For example localized target setting in SVL and VE shows that in determining performance targets both entities prioritise themselves and do not trade-off targets for each other.

Does it set aligned objective performance benchmarks for all supply chain partners?

Gunasekaran et al. (2004) argues that one of the hallmarks of an effective and efficient supply chain performance measurement approach is its ability to align performance targets for all partners. A look at the both the performance targets and actual performance of both SVL and VE shows considerable lack of alignment between the two. The amount of stocks kept by both entities is a good indicator of the opportunity lost due to this lack of alignment. SVL target to keep 110 days cover of oil and additive stocks while VE (at aggregate level) targets to keep 85 days cover of stock – between the two businesses nearly 200 days cover of stock is the target. There is no evidence of any engagement between the two entities to discuss optimization of stocks across the supply chain and harness the potential opportunity that lies in excess stocks.

SVL tracks OTIF as a performance measure but this measures the availability of product ‘on time in full’ for loading and dispatching to VE customers. VE countries do not track the OTIF performance at the point when they receive product into their warehouses, therefore freight process performance is not tracked properly. One of the issues raised by VE countries is the late arrival (and in some cases ‘too early’ arrival) of orders from SVL and the misalignment of the OTIF measure makes it difficult to investigate the root causes and tackle the problem.

Does performance measurement assess contribution of each supply chain partner to the overall performance, and ensure that risks and rewards are equitably shared?

The ability to assess each supply chain partner’s contribution to the overall performance of the supply chain is also a key attribute of effective supply chain performance measurement (Estampe et al., 2013). This also enables another key attribute of effective supply chain performance measurement - the ability to share risks and rewards equitably, according to Elrod et al. (2013). It is accepted by both SVL and VE that both businesses share a similar vision and objective of growing the business in Africa. In this light one would expect that performance measurement in the supply chain would be integrated to the extent of showing the part played by each of the two parties towards achieving the vision. For example when VE fail to meet its customer requirements (as measured by OTIF), it should be clear how much VE and SVL contributed to this loss. Similarly in cases when SVL fails to supply product the loss in OTIF should be apportioned to both SVL and VE based on their contribution to the root causes. Such integration is however not evident, the lack of lower level diagnostic measures and localised target setting are enough testimony of the absence of integration in this regard.

Is it dynamic enough to deal with the dynamic nature of the supply chain?

Kaplan and Norton (1993) argue for new performance measures to assess new goals and strategies. Gunasekaran and Kobu (2007) questioned whether the existing supply chain measures then, were still suitable for the supply chains that have become more global and complex. Cai et al, (2009) advocate for supply chain measures that are dynamic enough to respond to the dynamic nature of the supply chain. Perhaps the dynamism of the VE lubricants supply chain can best be seen in the change in oil price over the two year period – from $1.06 per litre in January 2014 to $0.60 in December 2015. Such a change, in arguably the most critical driver of costs in the VE lubricants supply chain, warrants that either performance approach or targets be changed to reflect the changing operating environment. There is however no evidence of new measures in both SVL and VE over the 24-month period, or changes in targets to key measures. The potential exposure of high stock holding in an environment of declining oil price would logically call for a reduction in stocks, however this did not come out in performance measures or targets of either SVL or VE.

The dynamic nature of the supply chain may also dictate that during the course of the measured horizon, the achievement of one measure's target maybe compromised by the operating environment. In such a case it may be prudent to compensate for that somehow in the other remaining measures. In VE and SVL performance measures there are no insights of how to compensate between different measures – the example of oil price movement versus stock holding demonstrates that.

Is it accurate and reflective of actual performance?

Gunasekaran et al. (2015) asserts that performance measurement should reflect the actual performance of an entity. Due to the quantitative nature of most of the measures identified, it could not be disputed whether the measurements reflected the reality of the functioning of the supply chain. Measure related to cost, customer service and stock holding could be safely classified as reflecting actual performance.

5.2.3 *Barriers to integration*

Ramanathan (2014) cites mistrust, too much internal focus, and insufficient definition of benefits, over-reliance on relationships and misalignment of priorities between partners as some of the barriers to integration in the supply chain. In the list of issues given as hampering the performance of the supply chain, one can conclude that some of these barriers to integration are insinuated. Targeting stock levels of up 180 days (6 months) in some operating units, in a supply chain where orders are placement on a monthly basis, is in part a statement of lack of trust in supply reliability of SVL. In the same way, a target of 110 days (nearly 4 months) of stock by SVL is a statement of low levels of trust in the forecasts given be VE. Localised target setting by VE entities and SVL epitomizes internal focus and the misalignment of the resultant performance targets breeds misaligned priorities. So despite the two companies being affiliates with the same shareholders, VE and SVL work as autonomous entities and make decisions based on what they perceive to be best for them rather than the entire supply chain – as argued by Saetta et al (2012). The autonomous operation of VE businesses also extends to within VE – there is very minimal sharing of performance issues and best practices between the different VE operating units.

The outcomes of the interviews show that both VE and SVL cannot quantify the potential benefits of improving their performance and neither can they both quantify the potential improvement of measures if they integrate more with each other.

5.2.4 *Summary of discussion pertaining to Proposition 1*

Performance measurement in the case study supply chain is done via the use of a set of standard performance indicators. However the approach does not fully satisfy the requirements of an effective performance measurement system due to localised target setting which breeds the possibility of unrealistic and conflicting targets. Existing measures also lack robust diagnostics that would assist in identifying performance problem areas leading to continuous improvement. From a supply chain point of view the performance measurement approach is too inward-focused and fails to drive the optimization of the entire chain. It also looks static in light of the current dynamic, complex and global supply chain.

5.3 Discussion pertaining to Proposition 2

5.3.1 *Operating units DEA*

Benchmarks

DEA identifies benchmark DMUs through comparison of efficiencies (Shafiee, Hosseinzadeh Lotfi, & Saleh, 2014). The output of the OU DEA model shows that Morocco, Guinea and the VE targets are the benchmark operating units, which are the peer units for all the other units. Since the VE targets DMU is a ‘fictitious’ DMU it is impossible to use it as a practical benchmark for the operating units despite DEA outcome showing it as a benchmark. Morocco and Guinea are therefore the operating units that can assist all the other units with best practices in order to improve efficiencies. DEA assumes that DMUs are homogenous and hence can emulate each other and improve performance (Charnes et al., 1978).

Burkina Faso, Ghana, Kenya, Senegal, Tunisia and Uganda all have both Morocco and Guinea as benchmarks. Therefore interactions between these six inefficient operating units and the benchmark units (Morocco and Guinea) should assist with sharing of supply chain best practices that can lead to improvement of their performance. Botswana, Cote D'Ivoire, Mali, Mauritius, Mozambique and Namibia have only Guinea as the benchmark unit; this means that these six units can only learn best practices from Guinea as a way of improving their performance.

Cape Verde and Madagascar do have their benchmarks as the fictitious VE targets DMU. Cape Verde also has the actual VE performance DMU as a benchmark. Since these two units are 'fictitious' this means that Cape Verde and Madagascar do not have genuine benchmarks to learn from. The only way for these two to find a benchmark is to look internally and identify the months when they have performed better than the average that has been used in the OU DEA model. This will be covered under window analysis.

Although the VE targets DMU is 'fictitious' and hence has been discarded as a credible benchmark for the genuine operating units, its classification as a benchmark DMU suggests that the overall targets of the VE measures are objectively in line with efficiency. Considering that the VE target DMU is a benchmark of the VE actual performance DMU, among many more other DMUs, one can infer that this suggests that the aggregate VE targets are credible targets for the VE lubricants supply chain. However, when one considers the approach employed to set that targets as described in 4.2.2 it is debatable whether this is deliberate or accidental. Further questions can be raised on whether all the targets are achievable simultaneously considering that the VE target DMU is the only fictitious benchmark DMU that is not represented by actual performance data.

Input excesses

Although the OU DEA model is output-oriented, inputs excesses are reflected on some operating units; these are a result of the presence of some slacks in some inputs (Cooper et al., 2006; Huguenin, 2012). Input excesses show that 8 operating units (Namibia, Cape Verde, Madagascar, Mozambique, Mauritius, Cote D'Ivoire, Botswana and Mali) are operating with excessive stock holding. This is in agreement with logical expectation considering that these 8 units have the highest days cover among the 16, except Botswana and Mali. The interpretation of this particular outcome of the DEA shows that keeping excessive amounts of stocks in these countries is not helping them improve their customer service and sales objectives. Converting this excess stock cover into actual stocks (based on corresponding stock held in 2015 by these operating units) shows that between the 8 operating units, VE has 3,735 million litres of excess stock. This presents a massive opportunity for VE; specific actions required to reduce stocks can be formulated through the respective operating units learning inventory management practices from their benchmarks – Morocco and Guinea.

COGS input excesses are seen in Burkina Faso and Cape Verde. The portfolio of products that an operating sells in their respective markets mainly drives the COGS. Besides negotiating better prices from SVL and better rates from transporters who transport product to VE, the only control that a VE operating unit can exercise on COGS is to change the composition of the portfolio by replacing products with high COGS with products with low COGS. Using this argument, Burkina Faso and Cape Verde can improve their performance through this kind product substitution. Otherwise excess in COGS can be argued to be theoretical as most of the control is largely outside VE's management.

All operating units, except Cape Verde and the benchmarks, show excesses in lead-time. The manufacturing lead-time is almost entirely influenced by SVL, almost entirely out of the control of VE management. However, as the interviews with SVL established, poor forecast accuracy on the forecast provided by VE operating units to SVL also contributes to the long and unstable manufacturing lead times shown by SVL. Mozambique shows the biggest excess in lead-time of 20 days while Burkina Faso and Mauritius show the smallest excess of 5 days. Perhaps the more important insight on manufacturing lead-time is the different manufacturing lead times that would result in 100% efficiency of the different operating units. This, one can argue, means that the blanket manufacturing lead time target of 30 days does not necessarily assist all operating units equally – each operating units has specific lead time requirements which would assist with its efficiency. Using this argument, one can conclude that the target lead-time needs to be differentiated for the different VE operating units as opposed to one target of 30 days currently employed.

Output shortfalls

According to Cooper et al. (2006) an output oriented DEA model will show the shortfalls in the outputs by which a DMU is shy of performing on the efficiency frontier. The OU DEA model is output-oriented and therefore output shortfalls are recorded in all ‘inefficient’ operating units against OTIF, sales and profit margin, implying that there is opportunity for these operating units to improve their efficiencies by varying their OTIF, sales and profit margins. OTIF shows both positive and negative shortfalls; showing that some operating units’ OTIF scores are too high (at the expense of the other two outputs - sales and profit margin) while other operating units have genuine OTIF shortfalls. These operating units with excessive OTIF scores (Botswana, Cote D’Ivoire, Kenya, Madagascar, Mali, Mauritius, Namibia and Senegal) would rather reduce their OTIF and compensate that with increases in sales and profit margin in order to improve their overall efficiencies. This outcome needs to be interpreted while bearing in mind that there is no restriction imposed on the weights; which means all the three outputs have equal weighting and hence have to equally trade-off for higher efficiency. One can also infer that perhaps the high

OTIF scores in these operating units are achieved at high cost, which in turn compromises the profit margin. Cape Verde, Ghana, Mozambique, Tunisia and Senegal exhibit OTIF shortfalls – they can further improve their OTIF in order to improve their overall efficiencies.

Sales volume shortages are also recorded for all the inefficient operating units. The highest shortfall of 7.2 million litres is recorded against Cape Verde, implying that Cape Verde has an opportunity to grow its volume from 0.04 million litres to 7.3 million litres per month. Other high shortfalls relative to demonstrated actual sales, recorded against Mozambique (3.2 million litres per month versus demonstrated 0.2 million litres per month) and Namibia (2.4 million litres per month versus demonstrated 0.1 million litres per month). The sales shortfalls for these operating units would seem unrealistic considering that they project sales volumes to grow by more than 1000%. This is due to no restriction imposed on the potential additional sales volume that would achieve 100% efficiency. Prior knowledge would need to be incorporated into the DEA model, as demonstrated by Cooper et al. (2006), in order to reflect realistic sales projection. This is shown in the sensitivity analysis section where a restriction is imposed on the maximum potential sales volume for each operating unit.

Shortfalls on profit margin are reflected on all inefficient operating units; implying that all these units have opportunities to improve their profit margins per litre of product sold. The calculation of profit margin shows that its improvement can be achieved through either increasing the price to customers or reducing costs of delivering the product to customers. Increasing prices might be against the sales volume improvement objective that is reflected by the sales volume shortfalls. Therefore all inefficient operating units have to learn from their peer benchmarks (Morocco or Guinea) how to reduce transport and warehousing costs in order to improve the profit margin. One can also check if there is not opportunity to increase prices for some products without impacting the sales volume potential. In line with expectation, some of the highest profit margin shortfalls are recorded against the operating with the poorest profit margins (Cape Verde, Mozambique and Namibia). This can be used to argue that the DEA output is indeed aligned to current performance as viewed through the employed measures – an indication that DEA output is indeed representing actual performance (Gunasekaran et al., 2015).

All excesses and shortfalls need to be taken in the right context of the assumptions made for the OU DEA model. The assumption of Constant Returns to Scale (CRS) means that output is expected to improve constantly with improvement in input regardless of the size of the operating unit in question. Because of this assumption some massive shortfalls on sales of are reported against some operating units and sales are projected to be higher by more than 1,000%. A restriction on the full potential of sales volumes, for instance, based on prior market knowledge, in the DEA would resolve give realistic sales volume projections (as shown in the sensitivity analysis section). Similarly other restrictions can be imposed on the performance variables that have been used and the associated weights in order to make the output of the analysis more realistic and reflective of management prior knowledge and objectives.

5.3.2 *Window Analysis*

In this study the window analysis of each entity serves two purposes – to determine the stability of the performance of the entity and to show the maximum operating efficiency an entity has achieved based on its performance history. Since the OU DEA model is based on averages of performance measures, there are months when each operating unit demonstrates above-average performance and hence demonstrates better efficiency that the one calculated by OU DEA model. There are, also, months when demonstrated performance is below average. Therefore each operating unit can find an internal benchmark performance within its own performance history before even looking at the benchmarks of Morocco and Guinea. This way an operating unit can identify performance measures that need improvement and the gaps against demonstrated benchmark performance.

Mozambique

Mozambique, one of the least efficient operating units from the OU DEA model results, shows 5 months (May 2014, July 2014, August 2014, October 2015 and December 2015) with relative efficiencies of 100%. The permutations of input and output performance measures for these 5 months can be the first benchmarks / targets for Mozambique in its performance improvement initiative. The permutations, arguably, present more credible targets than the set targets used by Mozambique since they have been demonstrated already in Mozambique. In other words, if Mozambique can consistently replicate the performance demonstrated in these 5 months, performance would significantly improve. As expected, there are months with efficiencies of less than 100%; the input excesses and output shortfalls of these months help to show the areas of improvement in order to increase efficiency.

The input excesses for Mozambique's window analysis show that for most of the months, day's cover of stock and actual stock quantity are both in excess. On average, across the 24 months, Mozambique shows 54 days cover of stock in excess of levels that would positively impact the OTIF, sales volume and profit margin. Physical stock is in excess by 0.2 million litres through the 24-month period. Therefore one of the high priority actions required in Mozambique in order to improve its supply chain performance is the reduction of stock levels. No input excess recorded against COGS suggests that COGS should be the least priority measure to address if in need of performance improvement of Mozambique. Lead-time is also not a priority, as it shows excess in only three months during the 24 months.

Output shortfalls derived from the window analysis for Mozambique manifest in all months with less than 100% efficiency for sales volume and OTIF. However the predominantly negative OTIF shortfalls mean that Mozambique is achieving high OTIF levels at the expense of sales volumes and profit margin. With the three output measures equally contributing to efficiency, Mozambique would need to improve sales volume and profit margin to compensate for the reduction in OTIF that is needed for overall efficiency improvement. Required improvement in sales volumes is, on average, an additional 0.1 million litres per month accompanied by a profit margin improvement of $0.01 per litre.

The insight from the output shortfalls from the window analysis compared to the shortfalls from the OU DEA model is that shortfalls from the window analysis are more ‘realistic’ and closer to demonstrated performance. This is because benchmarks are within the historical performance of the operating unit. For example while the OU DEA model results show a sales volume shortfall of 3.2 million litres per month for Mozambique, window analysis shows an average of 0.1 million litres per month. Profit margin shortfall from the window analysis is $0.01 for Mozambique, compared to $0.79 from the OU DEA model. While both benchmarks can be valid and be used, one as an external benchmark and the other as an internal benchmark, window analysis can also offer some form of validation of the performance gaps derived through the OU DEA model.

Benchmarks: Morocco and Guinea

The window analysis of the benchmark operating units, Morocco and Guinea, show that despite them being at 100% efficiency in the OU DEA model, they still have their own potential to improve. Because Morocco and Guinea, as benchmark operating units, have no other benchmark to learn from, they can observe the months when their performance has been at its best (100%) and use that performance as their benchmarks. By replicating the performance of the efficient months, Morocco and Guinea can improve their overall annual performance and further raise the bar for the rest of the operating units.

Morocco shows 100% efficiency in 9 months and Guinea achieves 100% efficiency in 6 of the 24 months. The performance measure permutations of these months can be used as the performance targets in order to drive performance improvement. Performance improvements can be directed by observing and the input excesses and output shortfalls over the 24 month period.

Morocco and Guinea window analyses also reveal that the targets set for the performance measures of these two units do not represent efficient performance. The same can be seen for the targets of Burkina Faso, Cape Verde and Mali – the targets do not represent 100% efficiency for their respective operating units. Guinea and Morocco targets represent efficiencies of 77.8% and 74.6% respectively, which are not only lower than the benchmark months but also are lower than some of the ‘inefficient’ months’ performances. This would suggest that the targets of these operating units have not been set through a robust and objective approach. These units would benefit from using a different set of targets – presumably starting with any set from the permutations that give 100% efficiency from the window analyses.

VE and SVL window analysis

The window analysis results of VE and SVL can be interpreted in a similar way as done for the operating units; showing which month(s) performance has been best and which month(s) performance has been poor. Since VE predominantly takes inputs that are determined by the performance of SVL, months when both SVL efficiency and VE efficiency is 100% are of particular interest. The months that show 100% efficiency for both SVL and VE can be singled as month when the supply chain as a whole is performing at its demonstrated maximum potential and presumably optimal level. From the results, the months of May 2014, June 2014, and November 2015 are the months when the supply chain is operating at its maximum potential.

In some months, SVL is operating at 100% efficiency while VE is not and vice versa; this can be interpreted as a manifestation of the independent decision-making that characterizes the behaviour of supply chain partners. If the efficiencies of SVL and VE are considered in isolation then the opportunity to manage and optimize the supply chain as a whole gets lost.

It is important to note the time factor behind performance measures. The performance recorded for the 3 months when the supply chain performance is optimized (May 2014, June 2014 and November 2015) may relate to activities that do not necessarily belong to these particular months. For instance, the profit margin reported by VE is on product that has been held in stock for more than two months while the lead-time recorded for the same months is for product that would only get delivered to VE warehouses more than a month later. Therefore to argue on the basis of these measures and associated DEA model that these particular months represented optimized supply chain management is simplistic. The time factor behind measures is critical if the management and measurement of performance is done on the supply chain as a whole.

5.3.3 *Sensitivity Analysis*

Peng Wong and Yew Wong (2007) and Goedhals-Gerber (2010) cite the dynamism of the supply chain as an impediment to the full deployment of DEA for supply chain performance evaluation. This study uses the sensitivity analysis to get some insights into the dynamism of the VE lubricants supply chain. The first sensitivity analyses are done by constraining the sales volume output, in line with assumed prior knowledge of the realistic potential sales volume in the operating units. This, in effect, tailors the OU DEA model to be more representative of the VE lubricants supply chain as it assumes realistic boundaries on one of the outputs. The second sensitivity analysis is performed by varying the inputs and outputs of the identified benchmark units. Both sensitivity analyses serve a number of purposes; for the benchmark operating units, they build on the windows analysis results to check if these units are consistent benchmarks over the entire period under analysis and under the constrained conditions. For the rest of the operating units the sensitivity analyses check whether there is significant variance in efficiency when the benchmarks' efficiencies change and when constraints are applied to the variables. Such sensitivity is important to validate the pairing of operating units with their identified peer benchmark units.

From the sensitivity analyses results shown in 4.3.3, Morocco shows consistent benchmark status (100% OU DEA model efficiency) even in months when its window analysis efficiency is at its lowest (61.6%), for as long as the corresponding window analysis efficiency of Guinea is not 100%. This can be interpreted to qualify Morocco as a credible benchmark unit for all the respective 'inefficient' operating units, for most of the time under consideration. All the other operating units that have Morocco as their benchmark can therefore adopt Morocco's best practices, with confidence, as a way of improving their performance. However when Guinea's efficiency is considered and at 100%, Morocco needs to attain at least 93% efficiency in order to remain a benchmark unit.

Guinea shows consistency in all the months except in some specific cases when its window analysis efficiency is from 75% to 88% and Morocco is 93% and 100% efficient. Similar to Morocco, this consistency qualifies Guinea as a credible benchmark for the other units. Therefore Guinea's best practices can be considered robust enough to offer the other units performance improvement, if adopted. It is notable though that Guinea's ceases to be a benchmark at 75%, 81%, 85% and 86% efficiencies when Morocco is 93% efficient. However for the same efficiencies, Guinea re-emerges as a benchmark when Morocco is 100% efficient. This unusual instability in efficiency is driven by the underlying input-output permutations behind the efficiency scores.

For all the other operating units there is a general negative correlation between their efficiency and the window analysis efficiencies of the benchmark units. This is logically expected – the higher the efficiency of the benchmarks units the higher the standard against which all other units are measured and therefore the lower the efficiency of all the other units. It is however important to note that despite this general correlation, there is significant ‘noise’ in the efficiencies exhibited by the rest of the units in response to varying benchmarks’ efficiencies. This noise indicates that the permutations of the input and output variables (rather than the overall efficiency) drive the relative efficiency of operating units. This would also suggest a confirmation and manifestation of the dynamism of the operating environment of VE lubricants supply chain.

It is also very important to note that the 3D surface charts used to show the results of the sensitivity analysis simply interpolates the surface between the observations to give a smooth surface. However this may be an over-simplification of the results due to insufficient observations. The efficiencies of operating units do not necessarily vary smoothly (as suggested by interpolation) as the benchmarks’ efficiencies increase or decrease. This can be seen in the case of Tunisia where it exhibits two different efficiencies for the three months Morocco exhibits 100% efficiency. This ‘instability’ of Tunisia’s efficiency can be attributed to the difference in input and output permutations underneath Morocco’s efficiency. In other works the three months than Morocco shows 100% efficiency have got different combinations of inputs and outputs which have different impacts on the efficiency of Tunisia. Better clarity on the sensitivity can be achieved by making more and more observations – a significantly higher number of observations would be needed to get a surface that correctly approximates the variation of operating units’ efficiencies.

5.3.4 *DEA and supply chain performance evaluation*

Khare et al. (2012) advance the argument that an effective and efficient supply chain performance measurement system should be able to address the extended nature of the supply chain. This means that such a performance measurement approach should cater for affiliates, suppliers and customers of the focal firm. The use of aligned performance measures between SVL's outputs and VE's inputs enables DEA to evaluate both businesses simultaneously and establish performance targets that promote the optimization of the entire supply chain. Therefore DEA based supply chain performance evaluation can achieve the elevation of the whole supply chain's performance above the performance of the individual parts as argued by Vaidya and Hudnurkar (2013). The DEA model calculated the relative performance of each operating unit, ranking them from best to last. It also identified the operating units (Morocco and Guinea) that could be used as benchmarks by other operating units for performance improvement. All operating units could also find benchmark performance levels from their own historical performance via the window analyses. This means that Gunasekaran et al. (2004)'s argument for objective performance benchmarks for all supply chain partners can be answered by DEA. The use of prior management knowledge to fine-tune the DEA model (as was done with restriction on sales volume) makes DEA dynamic and flexible to apply to changing environment. Therefore performance against new goals and strategies can be achieved (Kaplan & Norton, 1993).

5.3.5 *Summary of discussion pertaining to proposition 2*

The use of DEA to assess the performance of the case study supply chain gives a different dimension to supply chain performance measurement; it enables ranking of supply chain partners based on one consolidated measure that represents all performance indicators used. DEA also gives realistic performance benchmarks for each supply chain player, which could serve as realistic performance targets, while also quantifying the improvement in indicators needed to achieve the targets. This way, DEA goes a long way in satisfying, not only the requirements of effective performance measurement, but also the requirements of effective supply chain performance measurement.

5.4 Conclusion

From the findings of the interviews, one can conclude that supply chain performance measurement in VE Lubricants supply chain does not completely achieve the goals of integration and collaborations because it does not promote the supply chain over the individual players in the chain (SVL and VE). Therefore the research proposition 1, which proposes that supply chain performance measurement in the Vivo Energy lubricants supply chain is still fragmented across the supply chain and does not foster integration between the supply chain participants, is true.

The demonstration of a DEA-based supply chain performance methodology answers most of the requirements of an effective supply chain performance measurement system in terms of equitable evaluation of all supply chain players and optimization of the entire chain. Therefore the research proposition 2, that Data Envelopment Analysis (DEA) can offer an alternative supply chain performance evaluation methodology that covers the entire chain and shows contributions of all the players to the overall performance of the chain, is true.

CHAPTER 6. CONCLUSIONS & RECOMMENDATIONS

6.1 Introduction

This chapter presents the summary of the findings on the two propositions made as well as the conclusions. This is followed by recommendations to supply chain managers and any stakeholders involved in managing today's extended and global supply chain; regarding effective supply chain performance measurement and the use of DEA as an alternative for supply chain performance measurement. That chapter concludes by listing some of the limitations of this study and suggestions for future research to address these limitations and other arising questions.

6.2 Conclusions of the study

6.2.1 *Performance measurement in VE Lubricants*

The performance measurement approach and the performance measures used in the VE lubricants supply chain do not fully satisfy the benchmarks of effective performance measurement. On a positive note, the performance measurement is aligned with VE's strategic objective of delivering product to customers on time and in full requested volume. All performance measures are quantitative and hence give an objective and fact-based (as opposed to subjective) assessment of performance. Gaps were however found on the target-setting approach, which is too internally focussed without due consideration of any credible external benchmarks and ignores the inter-dependencies that potentially exist between the different players in the supply chain. This, therefore, results in potential misalignment of performance priorities and objectives of the different players involved. Poor target setting also results in unrealistic performance targets that are either unachievable and or too generous. The lack of a performance measure hierarchy means that there are no lower level diagnostic performance measures that are critical for identifying root causes of performance gaps and hence drive specific areas of performance improvement. It would seem that some measures in VE lubricants have not improved due to this.

Effective supply chain performance measurement addresses the extended nature of the supply chain by catering for all the relevant partners in the chain. In this regard, performance measurement in the VE lubricants supply chain is still highly fragmented; SVL, and the individual VE entities have localized performance measures that do not measure the supply chain as a whole. As a result, the optimizations of individual parties in the supply chain take precedence over the optimization of the entire chain thereby resulting in a potentially sub-optimized supply chain. The contributions by each of the parties to the performance of the supply chain cannot be objectively quantified and therefore the necessary trade-offs between parties are impossible. Lastly the employed performance measures and performance measurement approach are not dynamic enough to respond to the dynamic supply chain.

6.2.2 *DEA based supply chain performance evaluation*

Data Envelopment Analysis has been demonstrated as a way to enhance the performance measurement of the supply chain. This approach addresses some of the key requisites of an effective supply chain performance measurement system. It give an objective performance ranking of supply chain partners by using a single measure of efficiency; which makes comparison easier than when multiple measures are used simultaneously. DEA gives realistic performance benchmarks for all supply chain players through the use of empirical performance data of other players of demonstrated historical performance of the party in question. The performance gaps to be closed in order to achieve the benchmark performance are also calculated by DEA in each of the measures tracked. DEA can therefore assist to improve the performance measurement of today's increasingly complex and global supply chain, in a way that fosters collaboration and integration between the supply chain partners. It is however important to have adequate prior knowledge of the supply chain and its operating environment in order to tailor the DEA model to represent the real operating conditions. Without adequate prior knowledge, the DEA outcomes may not accurately reflect the actual performance of the supply chain thereby missing valuable improvement opportunities.

While the dynamism of the supply chain, as seen in the stochastic nature of performance data, poses a challenge for the traditional DEA models, which require data to be deterministic, window analysis and sensitivity analysis of DEA outcome can give a view of the stability of the performance of each supply chain player relative to others.

6.3 Recommendations

Supply chain managers in the VE lubricants supply chain would need to consider the following in order to improve the performance of the supply chain: robust performance targets setting; inter-organisational performance measurement; more diagnostic performance measures and improved collaboration between supply chain partners.

6.3.1 *Targets setting*

Setting of targets collaboratively between supply chain partners with objective trade-offs would be critical in order to align the performance goals of all the partners in the supply chain, especially SVL and VE lubricants entities. Targets that are aligned with the optimization of the entire supply chain would limit the potential conflict between the parties and drive integration and collaboration. Realistic and stretching targets are necessary in order to challenge and motivate and therefore efforts need to go into drafting targets that are objective, realistic and stretching. Targets that are either too generous or impossible to achieve do not only demotivate but also indicate a general lack of rigour in the target setting process.

6.3.2 *Intra-organisational performance measures*

In order to promote integration further, SVL, VE entities and VE customers should introduce more externally facing performance measures. Examples of such measures that can be used by VE entities to assess the performance of partners are:

Supplier OTIF: the number of orders delivered to the first VE warehouse on time and in full as a percentage of all orders placed during the period under review. This measure could be used by VE to assess the performance of SVL.

Delivery lead-time: The time, in days, taken from order placement by a VE operating unit to time of receipt of the order in the VE warehouse. This lead time should include the manufacturing lead time of SVL, the transportation lead time and any other time taken doing activities associated with the ordering process.

Forecast Accuracy: the variance between the actual quantities of product ordered by VE customers versus what would have been forecasted two months prior to the month under consideration. Forecast accuracy would complement the OTIF measure that is tracked by VE operating units against customer orders.

Such Inter-organisational measures will form a basis for performance-related interactions between the parties and also help to quantify the trade-off between parties' performance goals.

6.3.3 *Diagnostic performance measures*

Current performance measures in the VE lubricants supply chain cannot facilitate effective root-cause analysis because they lack adequate vertical granular details. Introducing lower level performance measures would significantly enhance VE lubricants supply chain performance measurement since it would narrow down areas of performance gaps.

6.3.4 *DEA for supply chain performance measurement*

DEA can offer an alternative or enhancement to supply chain performance measurement. Its characteristics go a long way in addressing most of the key requirements of effective supply chain performance measurement. It can deal with the extended nature of the supply chain measuring suppliers' and customers' performance in parallel to determine an optimized supply chain. It can be used to quantify the contributions of all the partners to the performance of the supply chain and it also offers empirical benchmarks for each partner. Incorporation of management knowledge and insights enhances DEA to cater for different conditions in the operating environment hence making the measurement approach dynamic and flexible.

6.4 Suggestions for further research

The use of a case study prevents statistical generalisation of the outcomes of this research. Therefore more studies on the state of supply chain performance measurement approaches need to be done in order to establish whether they are effective in promoting integration in today's global and complex supply chains. The use of DEA to objectively measure supply chain performance needs more research especially in the following areas:

- More detailed sensitivity analysis that reveals the actual variation of performance for all possible performance permutation underlying the efficiency numbers. A higher number of performance observations enable better clarity of the sensitivity of DMU performance to other DMUs. It is also important to note that only two DMUs were used to run the sensitivity analyses whereas all the DMUs have an impact on the relative efficiency of a particular DMU. Therefore enhanced sensitivity analysis would also take into account the sensitivity to all the other DMUs.

- The view of sensitivity analysis can also be done taking into consideration the probability distribution function of the efficiencies. The stochastic nature of the supply chain performance suggests that the relative efficiency of a DMU might exhibit some form of probability distribution. This distribution can be used to amplify the sensitivity surface chart presented thereby offering more insights into the probability of specific efficiency levels.
- The feasibility of setting supply chain performance targets as a set of permutations that give the desired efficiency, as opposed to a single combination, can also be investigated further. DEA shows that there are many performance permutations of performance that can result in 100% efficiency. Therefore the management of the supply chain in complex environments can also benefit from a set of possible performance target permutations rather that one set.

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APPENDIX A: Interview Schedules

Vivo Energy

Name:	Role:	Date:
VE Operating Country:	Key Lubricants Suppliers:	Key B2B Lubes Customers:

1. Who are your key suppliers and customers for your Lubricants business?
2. What are the key performance measures that you use to manage your lubricants supply chain? Against these key KPIs how well are you performing compared to this year's targets?
3. Do you measure the performance of your suppliers and B2B customers? What supply chain KPIs do you use to evaluate their performance? How well (or bad) have your suppliers and customers performed this year against your expectations?
4. How do you set targets or expectations for your suppliers' and customers' performance? Do you do that together with the suppliers and customers?
5. Do you review the performance of the supply chain together with your suppliers and customers? How often do you have these review meetings?
6. Are there any supply chain activities that you do in collaboration with your suppliers and customers (like forecasting, inventory planning etc? If so what are they?
7. What are the most critical areas / KPIs that you would like to see your suppliers and customers improve in order to positively impact your own supply chain performance?

8. How much improvement (in cost savings or your own KPIs improvement) would you see if your suppliers and customers were to achieve your expectations or targets?

Suppliers

Name:	Role:	Date:
Supplier:		Key VE Lubes Customers:

1. Who are your key Vivo Energy (VE) customers for your Lubricants business?
2. What are the key performance measures that you use to manage your lubricants supply chain? Against these key KPIs how well are you performing compared to this year's targets?
3. Do you measure the performance of your VE customers? What supply chain KPIs do you use to evaluate their performance? How well (or bad) have your VE customers performed this year against your expectations?
4. How do you set targets or expectations for your VE customers' performance? Do you do that together with them?
5. Do you review the performance of the supply chain together with your VE customers? How often do you have these review meetings?
6. Are there any supply chain activities that you do in collaboration with your VE customers (like forecasting, inventory planning etc? If so what are they?
7. What are the most critical areas / KPIs that you would like to see your VE customers improve in order to positively impact your own supply chain performance?
8. How much improvement (in cost savings or your own KPIs improvement) would you see if your VE customers were to achieve your expectations or targets?
9. Are there any areas in your supply chain that you believe you could improve even if the performance of your VE customers does not improve? Which are those?

Customers

Name:	Role:	Date:
Customer:		Supplying VE Country:

1. Who is your key Vivo Energy supplier of lubricants?
2. What are the key performance measures that you use to manage your lubricants supply chain? Against these key KPIs how well are you performing compared to this year's targets?
3. Do you measure the performance of your VE supplier? What supply chain KPIs do you use to evaluate their performance? How well (or bad) have your VE supplier performed this year against your expectations?
4. How do you set targets or expectations for your VE suppliers' performance? Do you do that together with them?
5. Do you review the performance of the lubricants supply chain together with your VE supplier? How often do you have these review meetings?
6. Are there any supply chain activities that you do in collaboration with your VE supplier (like forecasting, inventory planning etc? If so what are they?
7. What are the most critical areas / KPIs that you would like to see your VE supplier improve in order to positively impact your own supply chain performance?
8. How much improvement (in cost savings or your own KPIs improvement) would you see if your VE lubricants supplier were to achieve your expectations or targets?
9. Are there any areas in your lubricants supply chain that you believe you could improve even if the performance of your VE lubricants supplier does not improve? Which are those?

APPENDIX B: PERFORMANCE INDICATORS

Days on Hand

Month	BF	BW	CI	CV	GH	GN	KE	MA	MG	ML	MU	MZ	NA	SN	TN	UG	VE
TARGET	**180.0**	**90.0**	**120.0**	**244.0**	**110.0**	**120.0**	**33.0**	**16.0**	**288.0**	**90.0**	**150.0**	**120.0**	**90.0**	**120.0**	**30.0**	**75.0**	**85.0**
Jan-14	279.8	308.5	100.6	139.8	119.3	103.7	29.4	17.9	198.4	159.6	150.3	283.1	182.4	68.9	54.3	77.0	78.9
Feb-14	168.5	599.4	135.0	202.5	119.6	93.0	29.7	15.7	306.3	120.9	131.7	71.2	200.5	82.7	51.1	85.9	75.1
Mar-14	179.9	293.9	102.4	179.3	134.7	147.6	29.3	15.6	386.1	101.3	105.5	87.9	269.1	68.9	42.6	79.2	74.1
Apr-14	160.7	249.1	88.5	177.7	72.7	75.5	24.7	15.6	193.4	86.6	98.1	103.6	240.1	116.9	34.4	84.7	62.7
May-14	158.6	266.2	101.8	230.5	262.6	74.8	24.7	18.6	158.2	116.1	110.8	38.0	179.0	108.2	29.7	78.8	67.1
Jun-14	190.7	134.3	146.6	271.1	52.4	103.8	31.2	16.1	206.6	100.3	145.4	1631.0	188.4	149.1	26.8	81.6	64.4
Jul-14	298.9	180.5	105.0	187.8	48.9	127.9	32.4	16.0	112.4	129.1	136.8	142.0	449.5	160.3	28.7	97.2	79.7
Aug-14	144.4	228.6	146.6	197.2	59.9	123.5	24.7	15.6	182.8	112.3	138.3	443.0	159.0	182.9	36.8	80.4	78.8
Sep-14	119.8	163.9	131.4	148.8	60.3	66.9	29.7	14.8	200.1	131.1	156.2	166.7	159.1	198.2	22.7	87.6	69.1
Oct-14	344.9	123.3	127.0	137.8	62.0	105.0	27.8	14.3	163.9	134.5	177.4	60.1	144.2	168.4	22.0	64.4	75.2
Nov-14	185.8	190.6	153.2	207.8	50.9	64.0	26.8	14.8	191.7	137.9	123.6	152.6	425.7	162.6	35.0	71.6	72.7
Dec-14	170.8	184.6	136.8	153.0	51.5	116.8	27.2	15.6	188.7	117.1	132.2	145.1	220.2	161.4	23.5	56.8	71.3
Jan-15	145.1	104.5	121.4	254.2	76.9	105.7	24.8	16.2	217.8	139.7	249.7	252.3	236.3	127.1	43.1	66.4	82.9
Feb-15	248.8	120.8	145.0	223.3	86.2	118.5	25.8	16.2	285.6	123.2	202.7	234.4	234.0	145.7	40.5	57.3	87.6
Mar-15	115.9	79.5	121.3	292.6	88.4	6.6	27.2	16.3	345.4	104.5	154.8	273.2	473.3	6.3	35.3	47.0	57.8
Apr-15	111.6	104.1	124.6	329.3	153.4	108.6	25.6	16.2	202.7	106.5	103.3	128.3	205.0	115.4	36.4	66.3	84.6
May-15	145.7	131.3	134.9	388.4	107.7	132.9	25.8	16.7	327.2	97.8	147.5	104.0	203.2	119.7	35.2	61.3	83.5
Jun-15	50.8	87.5	137.6	310.4	78.1	160.9	27.5	16.5	218.1	102.9	111.8	497.7	127.2	107.2	44.0	65.0	72.7
Jul-15	87.1	118.3	138.8	310.4	69.6	128.1	27.5	16.3	193.8	81.6	108.3	34.3	122.6	94.7	54.1	83.0	75.5
Aug-15	125.3	91.4	118.5	370.0	97.6	148.6	26.6	17.0	331.4	102.1	116.4	37.5	263.0	93.6	46.8	63.8	80.2
Sep-15	234.5	128.3	105.9	328.0	66.7	120.0	161.2	16.3	274.7	104.5	126.3	151.7	182.8	94.7	32.6	53.1	89.1
Oct-15	94.0	68.9	106.3	240.2	69.8	100.3	28.1	18.3	207.6	89.0	122.0	294.6	663.6	99.1	34.7	73.0	65.5
Nov-15	102.1	93.9	97.1	209.0	48.3	127.6	21.3	12.8	237.0	96.2	182.5	163.1	271.7	86.8	29.2	78.7	59.4
Dec-15	212.4	160.0	152.5	208.8	37.5	103.3	37.9	30.5	229.0	72.3	175.7	62.5	432.6	80.6	28.2	75.2	65.4
2015 Actual	132.1	104.0	125.7	282.5	80.2	109.2	38.6	17.3	249.6	100.9	143.1	186.1	279.0	96.1	37.9	65.6	78.1

Manufacturing Lead Time

Month	BF	BW	CI	CV	GH	GN	KE	MA	MG	ML	MU	MZ	NA	SN	TN	UG	VE
TARGET	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Jan-14	44	45	61	34	43	41	55	34	43	65	83	69	53	60	51	43	50
Feb-14	45	56	37	36	42	53	32	32	19	51	86	41	67	50	38	48	43
Mar-14	42	39	41	32	34	41	36	32	76	46	80	51	98	64	32	61	47
Apr-14	52	44	46	41	59	52	47	33	25	52	44	47	57	49	25	45	42
May-14	64	7	33	36	57	33	48	33	49	53	58	96	57	40	35	41	45
Jun-14	47	36	52	49	49	47	37	29	62	62	65	37	54	49	45	35	45
Jul-14	76	49	36	42	47	85	41	30	38	58	37	57	41	73	28	42	43
Aug-14	58	50	35	56	45	42	38	27	51	31	68	30	68	47	30	37	42
Sep-14	50	14	35	55	50	28	33	23	41	68	63	62	36	52	35	40	40
Oct-14	43	39	47	34	45	47	34	23	88	64	62	70	48	71	34	45	45
Nov-14	37	25	37	44	33	31	35	24	39	52	78	26	33	51	34	34	38
Dec-14	56	48	73	44	39	54	39	31	48	48	59	84	36	57	45	34	46
Jan-15	31	32	40	40	35	41	49	21	36	45	49	77	42	65	39	47	40
Feb-15	61	62	39	33	37	37	37	28	43	41	40	93	39	53	36	45	40
Mar-15	72	56	39	48	26	29	40	28	50	42	27	29	42	54	30	43	38
Apr-15	52	49	35	74	28	25	41	37	36	30	55	39	35	35	40	44	40
May-15	51	45	36	36	56	40	48	38	32	69	38	51	29	44	36	48	41
Jun-15	54	20	43	34	44	34	41	35	40	46	35	20	26	49	64	84	41
Jul-15	36	21	36	43	57	30	39	30	57	51	32	36	39	20	31	47	37
Aug-15	37	10	23	61	37	28	27	28	38	33	58	19	43	49	63	45	38
Sep-15	39	26	41	37	49	36	34	17	33	62	41	38	44	62	39	33	36
Oct-15	50	24	41	43	41	40	38	16	32	64	42	22	42	54	28	46	35
Nov-15	52	14	39	41	43	42	43	33	49	50	40	26	64	51	36	44	41
Dec-15	48	27	44	45	44	41	39	26	28	57	41	51	40	50	40	45	39
2015 Actual	47	41	37	39	39	34	37	29	38	43	38	52	39	47	35	46	38

Cost of Goods Sold

Month	BF	BW	CI	CV	GH	GN	KE	MA	MG	ML	MU	MZ	NA	SN	TN	UG	VE
TARGET	**3.96**	**2.08**	**2.00**	**2.48**	**1.89**	**2.35**	**0.92**	**1.73**	**1.90**	**2.03**	**2.29**	**0.90**	**1.80**	**2.30**	**1.47**	**2.41**	**1.88**
Jan-14	3.45	2.03	2.37	2.79	2.06	2.78	0.47	1.86	2.33	2.50	2.52	0.59	2.31	2.92	1.84	2.97	1.94
Feb-14	3.45	2.03	2.61	2.79	2.06	2.78	0.39	1.86	2.56	2.75	2.29	0.52	2.57	2.92	1.68	2.70	1.79
Mar-14	3.84	1.83	2.37	2.79	1.88	2.50	0.43	2.06	2.10	2.75	2.06	0.61	2.57	2.39	1.68	2.97	1.84
Apr-14	4.22	1.83	2.61	2.79	1.88	2.50	0.47	1.86	2.10	2.50	2.06	0.55	2.31	2.66	1.51	2.43	1.80
May-14	3.84	2.03	2.37	2.79	2.06	3.06	0.47	2.06	2.56	2.25	2.29	0.63	2.82	2.66	1.51	2.97	1.86
Jun-14	3.84	2.24	2.13	2.28	1.69	3.06	0.43	1.86	2.33	2.25	2.52	0.60	2.57	2.39	1.68	2.97	1.91
Jul-14	4.22	2.03	2.61	2.28	2.06	2.78	0.39	1.86	2.10	2.50	2.29	0.57	2.57	2.39	1.68	2.70	1.87
Aug-14	4.22	2.24	2.61	2.79	1.69	2.78	0.43	1.86	2.56	2.75	2.29	0.56	2.57	2.66	1.51	2.43	1.88
Sep-14	3.45	2.03	2.37	2.28	2.06	2.50	0.43	2.27	2.56	2.25	2.52	0.60	2.82	2.66	1.51	2.43	1.86
Oct-14	4.22	2.03	2.61	2.28	1.88	2.50	0.39	2.06	2.56	2.50	2.29	0.68	2.57	2.92	1.68	2.70	1.81
Nov-14	3.45	1.83	2.37	2.79	1.88	3.06	0.47	2.06	2.10	2.25	2.06	0.73	2.57	2.66	1.84	2.97	2.03
Dec-14	4.22	1.83	2.61	2.53	2.06	2.78	0.47	2.06	2.33	2.25	2.29	0.62	2.31	2.66	1.68	2.43	1.99
Jan-15	3.61	1.92	1.83	2.65	1.69	2.56	0.98	1.54	2.07	2.07	2.41	0.89	1.89	2.52	1.34	2.41	1.88
Feb-15	4.02	2.34	2.03	2.41	2.06	2.56	0.98	1.88	1.88	2.07	2.20	1.06	1.70	2.52	1.49	2.65	2.02
Mar-15	3.61	2.34	1.83	2.17	2.06	2.33	0.98	1.88	1.69	1.86	2.41	1.12	1.89	2.06	1.34	2.65	1.98
Apr-15	3.61	1.92	2.24	2.65	1.69	2.10	0.98	1.54	2.07	1.86	2.41	0.95	1.89	2.06	1.49	2.65	1.84
May-15	4.02	2.34	2.24	2.65	1.87	2.10	0.89	1.71	1.69	2.07	2.41	0.93	1.89	2.52	1.49	2.65	1.90
Jun-15	4.02	1.92	1.83	2.41	1.87	2.56	0.98	1.88	1.88	1.86	2.20	0.94	1.70	2.29	1.63	2.17	1.98
Jul-15	4.42	2.34	2.03	2.65	1.87	2.10	0.89	1.88	1.88	2.28	2.41	7.33	1.70	2.06	1.49	2.17	2.82
Aug-15	3.61	1.92	2.24	2.65	1.87	2.10	0.80	1.71	2.07	2.28	2.41	4.81	1.70	2.06	1.34	2.17	2.39
Sep-15	4.02	1.92	1.83	2.65	2.06	2.56	0.98	1.54	2.07	1.86	1.98	1.89	1.70	2.29	1.49	2.17	2.00
Oct-15	4.02	2.34	1.83	2.65	1.87	2.56	0.80	1.88	1.88	2.28	2.20	0.81	1.89	2.52	1.49	2.17	1.99
Nov-15	4.02	1.92	2.24	2.17	1.87	2.10	0.80	1.54	1.88	1.86	2.20	0.34	1.70	2.52	1.49	2.41	1.75
Dec-15	4.02	1.92	1.83	2.17	1.87	2.56	0.98	1.88	1.88	2.07	1.98	1.19	2.07	2.29	1.63	2.65	1.99
2015Actual	3.96	2.11	1.99	2.47	1.88	2.35	0.91	1.76	1.91	2.07	2.26	2.07	1.81	2.31	1.48	2.38	2.08

On Time in Full (OTIF)

Month	BF	BW	CI	CV	GH	GN	KE	MA	MG	ML	MU	MZ	NA	SN	TN	UG	VE
TARGET	93.0%	93.0%	93.0%	93.0%	93.0%	93.0%	93.0%	93.0%	93.0%	93.0%	93.0%	93.0%	93.0%	93.0%	93.0%	93.0%	93.0%
Jan-14	97.9%	71.2%	88.6%	95.6%	83.2%	89.9%	83.2%	57.5%	73.9%	97.6%	95.7%	73.5%	82.5%	99.1%	72.7%	90.5%	84.0%
Feb-14	99.5%	79.7%	91.1%	99.3%	76.1%	95.5%	88.1%	82.3%	82.4%	97.0%	88.9%	88.7%	84.2%	97.6%	86.3%	92.3%	88.5%
Mar-14	100.0%	94.2%	66.1%	99.7%	75.6%	85.2%	86.4%	65.9%	73.5%	100.0%	88.7%	62.3%	85.3%	100.0%	82.5%	88.7%	83.8%
Apr-14	91.1%	90.5%	86.5%	97.5%	80.0%	86.6%	89.1%	67.9%	94.4%	98.9%	93.0%	98.5%	72.8%	98.8%	90.2%	87.0%	86.9%
May-14	94.2%	93.6%	91.1%	96.7%	80.5%	84.4%	81.1%	65.5%	94.5%	99.7%	92.6%	76.8%	79.7%	95.4%	78.2%	83.1%	85.1%
Jun-14	94.2%	93.6%	91.1%	96.7%	80.5%	84.4%	81.1%	65.5%	94.5%	99.7%	92.6%	79.9%	79.7%	95.4%	78.2%	83.1%	85.1%
Jul-14	98.5%	75.7%	62.9%	99.0%	73.7%	86.2%	76.2%	42.6%	94.0%	98.7%	90.6%	99.5%	88.3%	97.4%	57.2%	86.6%	78.1%
Aug-14	98.2%	92.1%	92.2%	98.9%	67.3%	92.1%	74.8%	48.8%	88.2%	99.7%	94.5%	94.1%	89.7%	96.2%	52.2%	80.5%	80.5%
Sep-14	95.9%	92.7%	85.3%	98.8%	75.4%	88.1%	65.2%	50.4%	82.3%	99.6%	94.4%	72.2%	86.1%	99.2%	52.8%	77.1%	78.4%
Oct-14	78.4%	92.9%	82.1%	98.6%	71.7%	90.6%	64.6%	65.1%	96.7%	99.6%	93.9%	84.9%	87.5%	98.4%	49.5%	74.2%	78.5%
Nov-14	77.3%	93.3%	90.9%	99.5%	70.4%	89.3%	67.4%	66.9%	76.2%	97.2%	94.7%	61.6%	79.0%	95.6%	49.6%	79.2%	78.8%
Dec-14	84.1%	90.3%	90.6%	97.0%	74.0%	90.7%	57.9%	67.3%	82.0%	95.4%	95.1%	87.2%	74.6%	97.9%	54.7%	77.1%	78.4%
Jan-15	94.3%	86.3%	92.0%	97.7%	77.9%	91.4%	94.0%	81.8%	90.1%	90.9%	85.7%	78.0%	82.7%	99.3%	65.5%	74.9%	82.5%
Feb-15	94.5%	93.3%	95.0%	99.4%	90.3%	91.1%	89.0%	71.9%	94.3%	93.3%	83.9%	63.3%	78.7%	98.8%	68.0%	78.7%	82.6%
Mar-15	90.2%	92.8%	91.7%	99.8%	66.7%	89.8%	89.0%	85.8%	93.6%	97.3%	94.6%	94.6%	85.1%	98.5%	50.3%	77.1%	81.1%
Apr-15	88.6%	70.7%	89.8%	99.8%	79.5%	84.3%	86.0%	87.8%	91.0%	98.5%	90.9%	85.8%	83.5%	90.4%	56.5%	86.9%	82.0%
May-15	94.1%	84.0%	89.4%	100.0%	60.8%	72.7%	89.0%	84.8%	100.0%	96.1%	95.3%	86.0%	80.8%	96.9%	60.7%	85.1%	81.9%
Jun-15	97.3%	76.9%	81.1%	100.0%	67.6%	61.0%	95.0%	89.7%	91.2%	98.2%	94.9%	77.0%	74.4%	96.5%	55.5%	86.4%	82.2%
Jul-15	94.4%	90.3%	79.6%	98.8%	50.0%	79.2%	93.0%	80.1%	97.0%	94.3%	95.5%	94.7%	72.2%	97.9%	38.6%	88.4%	77.4%
Aug-15	93.7%	95.8%	88.3%	99.3%	61.0%	74.2%	95.0%	68.8%	95.5%	96.3%	95.8%	87.8%	74.4%	97.3%	42.7%	81.9%	80.4%
Sep-15	99.5%	92.5%	74.8%	99.6%	57.8%	82.4%	95.0%	66.5%	93.2%	98.2%	93.1%	82.7%	80.6%	98.0%	25.7%	71.4%	74.5%
Oct-15	99.8%	91.9%	82.3%	99.2%	59.2%	67.4%	97.0%	67.8%	92.7%	97.4%	94.6%	63.9%	81.9%	99.6%	34.9%	65.4%	73.6%
Nov-15	99.8%	98.7%	91.6%	100.0%	74.7%	91.7%	93.0%	64.6%	90.4%	100.0%	96.2%	69.5%	83.7%	96.9%	27.6%	82.6%	78.2%
Dec-15	98.7%	97.7%	77.0%	95.5%	71.8%	91.3%	57.8%	59.7%	91.3%	92.3%	83.3%	78.6%	72.7%	99.0%	21.2%	86.0%	79.5%
2015Actual	87.2%	88.5%	86.9%	99.4%	67.8%	80.5%	92.3%	77.2%	93.5%	96.4%	85.0%	80.7%	79.8%	97.3%	47.8%	79.9%	79.1%

Profit Margin

Month	BF	BW	CI	CV	GH	GN	KE	MA	MG	ML	MU	MZ	NA	SN	TN	UG	VE
TARGET	**0.48**	**1.06**	**0.97**	**0.77**	**0.52**	**0.86**	**0.65**	**0.48**	**0.86**	**0.68**	**0.61**	**0.05**	**0.27**	**0.70**	**0.64**	**0.49**	**0.61**
Jan-14	1.23	0.28	0.98	0.77	0.74	1.18	0.13	0.94	0.59	0.93	0.70	0.00	0.00	0.72	0.55	0.37	0.62
Feb-14	1.23	0.31	0.81	0.94	0.60	1.30	0.12	0.77	0.53	1.13	0.63	0.00	0.00	0.88	0.55	0.46	0.57
Mar-14	1.23	0.34	0.98	0.85	0.74	1.30	0.12	0.86	0.59	1.03	0.70	0.00	0.00	0.88	0.49	0.46	0.61
Apr-14	1.51	0.34	0.81	0.94	0.74	1.06	0.11	0.77	0.59	1.13	0.57	0.00	0.00	0.72	0.49	0.46	0.59
May-14	1.51	0.28	0.89	0.85	0.67	1.30	0.12	0.94	0.53	1.13	0.63	0.00	0.00	0.88	0.60	0.37	0.65
Jun-14	1.37	0.28	0.81	0.77	0.60	1.18	0.11	0.86	0.65	1.03	0.70	0.00	0.00	0.88	0.49	0.46	0.63
Jul-14	1.51	0.34	0.89	0.85	0.67	1.06	0.12	0.94	0.59	0.93	0.63	0.00	0.00	0.80	0.49	0.37	0.59
Aug-14	1.37	0.34	0.98	0.85	0.67	1.06	0.13	0.94	0.53	1.03	0.70	0.00	0.00	0.88	0.49	0.37	0.61
Sep-14	1.37	0.31	0.81	0.85	0.67	1.06	0.12	0.77	0.53	0.93	0.57	0.00	0.00	0.88	0.49	0.46	0.54
Oct-14	1.37	0.28	0.89	0.85	0.74	1.30	0.13	0.94	0.59	0.93	0.63	0.00	0.00	0.88	0.49	0.46	0.57
Nov-14	1.37	0.34	0.98	0.85	0.67	1.06	0.12	0.86	0.65	1.03	0.63	0.00	0.00	0.88	0.60	0.46	0.63
Dec-14	1.37	0.34	0.98	0.94	0.67	1.30	0.12	0.94	0.53	1.03	0.70	0.00	0.00	0.72	0.55	0.46	0.65
Jan-15	1.24	0.95	0.48	0.00	0.65	1.15	0.31	0.70	0.68	0.85	0.38	0.01	0.04	0.33	0.43	0.22	0.54
Feb-15	1.24	0.95	0.59	0.00	0.65	1.26	0.31	0.64	0.68	0.85	0.47	0.01	0.04	0.40	0.47	0.25	0.54
Mar-15	1.12	0.87	0.48	0.00	0.54	1.03	0.25	0.70	0.75	0.94	0.42	0.01	0.04	0.36	0.43	0.25	0.51
Apr-15	1.37	0.95	0.53	0.00	0.65	1.03	0.25	0.64	0.61	0.77	0.38	0.02	0.04	0.33	0.43	0.27	0.50
May-15	1.24	0.78	0.53	0.00	0.65	1.15	0.31	0.58	0.68	0.77	0.47	0.00	0.04	0.36	0.47	0.25	0.50
Jun-15	1.12	0.87	0.59	0.00	0.59	1.03	0.31	0.70	0.61	0.94	0.42	0.00	0.04	0.36	0.47	0.25	0.55
Jul-15	1.12	0.95	0.59	0.00	0.59	1.15	0.25	0.58	0.75	0.94	0.47	0.13	0.04	0.36	0.47	0.22	0.50
Aug-15	1.24	0.78	0.59	0.00	0.59	1.15	0.31	0.70	0.75	0.77	0.47	0.08	0.04	0.40	0.43	0.25	0.50
Sep-15	1.12	0.78	0.59	0.00	0.54	1.26	0.31	0.70	0.68	0.77	0.42	0.03	0.04	0.40	0.47	0.25	0.52
Oct-15	1.24	0.78	0.53	0.00	0.65	1.15	0.31	0.70	0.61	0.85	0.42	0.01	0.04	0.36	0.52	0.27	0.58
Nov-15	1.37	0.87	0.48	0.00	0.65	1.26	0.31	0.70	0.75	0.94	0.38	0.01	0.04	0.33	0.43	0.22	0.56
Dec-15	1.12	0.87	0.53	0.00	0.65	1.03	0.31	0.70	0.68	0.94	0.42	0.02	0.04	0.40	0.43	0.25	0.54
2015 Actual	1.21	0.86	0.54	0.00	0.62	1.13	0.29	0.68	0.68	0.86	0.43	0.05	0.04	0.37	0.45	0.25	0.53

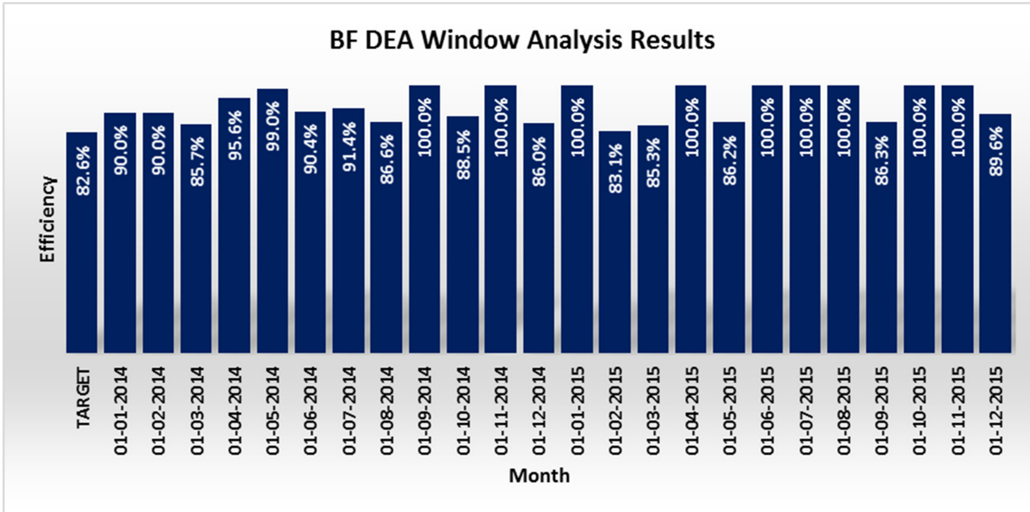
Sales Volume

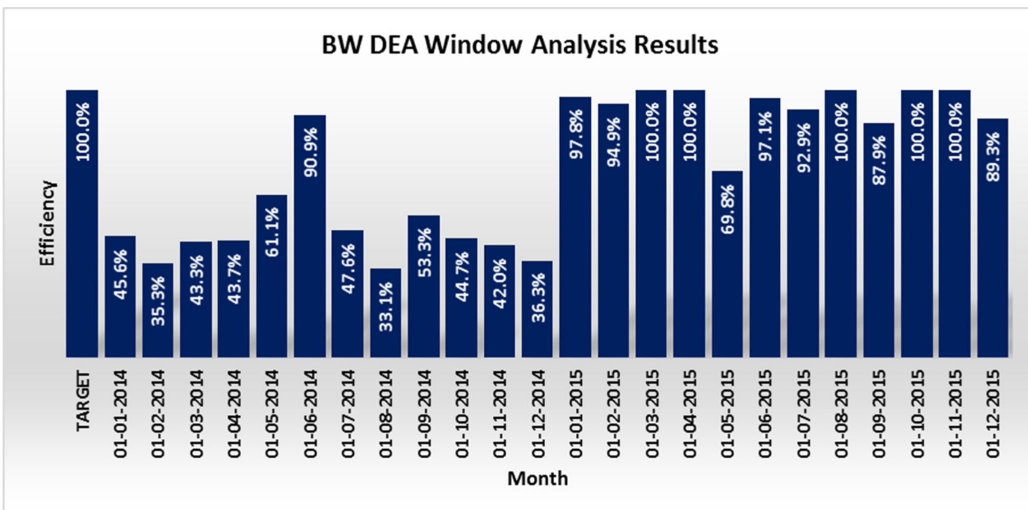
Month	BF	BW	CI	CV	GH	GN	KE	MA	MG	ML	MU	MZ	NA	SN	TN	UG	VE
TARGET	0.20	0.06	0.30	0.05	0.70	0.23	1.10	1.30	0.13	0.45	0.20	0.20	0.13	0.40	0.75	0.36	6.56
Jan-14	0.03	0.04	0.24	0.06	0.75	0.23	1.12	1.13	0.15	0.34	0.14	0.10	0.13	0.26	0.56	0.22	5.52
Feb-14	0.03	0.03	0.20	0.04	0.49	0.19	1.17	1.50	0.09	0.34	0.14	0.25	0.10	0.22	0.72	0.22	5.73
Mar-14	0.03	0.03	0.24	0.06	0.59	0.18	1.11	1.43	0.14	0.39	0.19	0.31	0.09	0.29	0.68	0.25	6.01
Apr-14	0.05	0.03	0.25	0.04	0.75	0.28	1.08	1.36	0.11	0.42	0.20	0.20	0.10	0.23	0.80	0.24	6.16
May-14	0.04	0.03	0.20	0.04	0.76	0.28	1.03	1.53	0.14	0.50	0.18	0.47	0.08	0.29	0.89	0.26	6.74
Jun-14	0.04	0.08	0.23	0.05	0.79	0.24	0.92	1.65	0.14	0.42	0.16	0.01	0.15	0.26	0.85	0.27	6.27
Jul-14	0.04	0.04	0.21	0.05	0.72	0.28	1.10	0.86	0.16	0.57	0.18	0.21	0.10	0.27	0.58	0.27	5.65
Aug-14	0.03	0.02	0.17	0.08	0.51	0.20	1.01	0.85	0.10	0.42	0.22	0.05	0.08	0.22	0.65	0.28	4.88
Sep-14	0.03	0.04	0.21	0.08	0.74	0.28	1.18	0.81	0.11	0.44	0.16	0.18	0.12	0.24	0.86	0.29	5.79
Oct-14	0.05	0.04	0.26	0.08	0.59	0.20	1.19	0.94	0.15	0.45	0.17	0.45	0.12	0.24	0.88	0.33	6.13
Nov-14	0.12	0.03	0.20	0.04	0.64	0.24	0.96	1.02	0.11	0.36	0.23	0.10	0.10	0.27	0.74	0.34	5.51
Dec-14	0.16	0.02	0.28	0.08	0.67	0.20	0.93	0.88	0.16	0.60	0.20	0.14	0.12	0.22	1.16	0.33	6.17
Jan-15	0.14	0.04	0.25	0.04	0.53	0.28	1.12	0.73	0.11	0.38	0.12	0.06	0.08	0.24	0.61	0.28	5.02
Feb-15	0.16	0.03	0.27	0.04	0.51	0.21	1.16	0.81	0.13	0.47	0.11	0.09	0.11	0.23	0.72	0.37	5.42
Mar-15	0.15	0.06	0.26	0.04	0.60	0.29	1.14	0.65	0.13	0.42	0.17	0.10	0.11	0.27	0.65	0.42	5.47
Apr-15	0.15	0.04	0.30	0.04	0.66	0.26	1.10	0.88	0.13	0.51	0.19	0.19	0.15	0.33	0.79	0.31	6.02
May-15	0.12	0.04	0.28	0.04	0.60	0.22	1.05	0.78	0.12	0.48	0.18	0.22	0.13	0.30	0.80	0.35	5.70
Jun-15	0.19	0.06	0.28	0.03	0.70	0.18	1.04	0.94	0.19	0.49	0.18	0.03	0.15	0.29	0.67	0.40	5.81
Jul-15	0.29	0.06	0.27	0.04	0.75	0.25	1.18	0.60	0.19	0.44	0.17	0.67	0.15	0.35	0.60	0.35	6.35
Aug-15	0.19	0.08	0.29	0.03	0.58	0.20	1.12	0.89	0.08	0.33	0.21	0.48	0.13	0.43	0.67	0.38	6.08
Sep-15	0.12	0.06	0.32	0.04	0.64	0.21	1.14	0.88	0.10	0.51	0.12	0.17	0.15	0.36	0.78	0.35	5.96
Oct-15	0.30	0.06	0.28	0.05	0.77	0.24	1.04	1.64	0.13	0.36	0.21	0.07	0.14	0.40	0.59	0.37	6.64
Nov-15	0.24	0.06	0.27	0.05	0.76	0.17	1.09	1.65	0.11	0.36	0.11	0.13	0.10	0.43	0.95	0.34	6.84
Dec-15	0.26	0.04	0.35	0.04	0.72	0.25	0.98	0.90	0.11	0.58	0.13	0.43	0.12	0.41	0.59	0.41	6.32
2015Actual	0.19	0.05	0.29	0.04	0.65	0.23	1.10	0.94	0.13	0.44	0.16	0.22	0.13	0.34	0.70	0.36	5.97

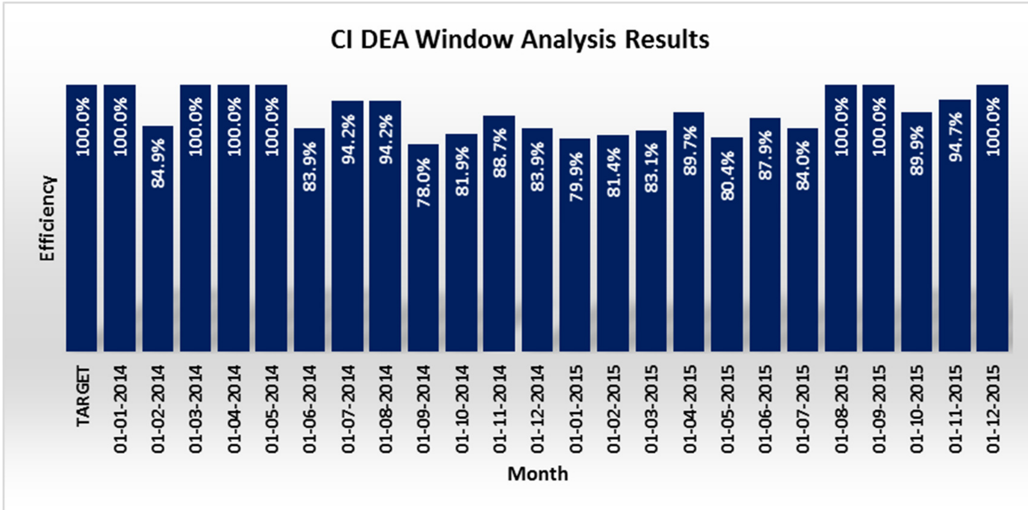
Stocks

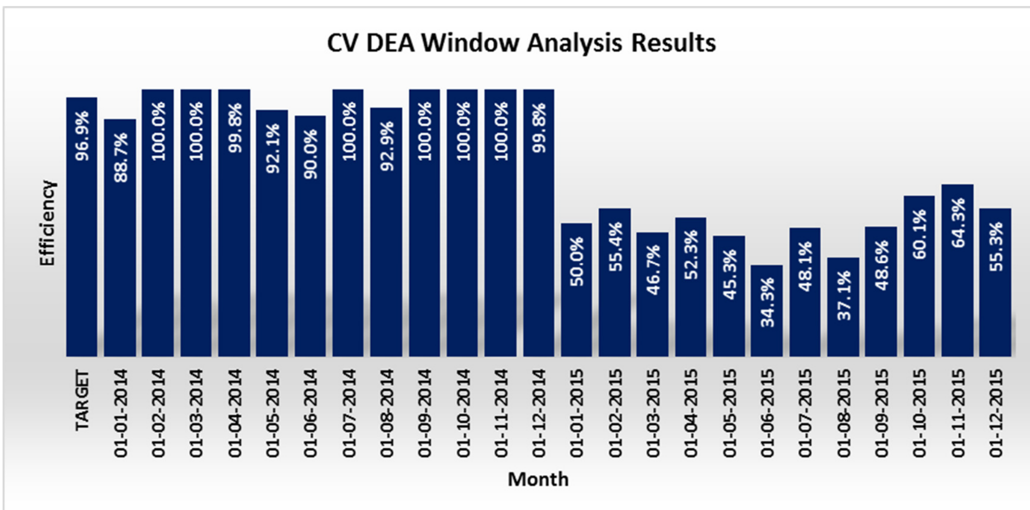
Month	BF	BW	CI	CV	GH	GN	KE	MA	MG	ML	MU	MZ	NA	SN	TN	UG	VE
TARGET	1.7	0.3	2.2	0.7	2.6	0.9	1.5	1.3	1.2	1.9	0.9	0.7	1.2	1.6	1.2	1.1	20.7
Jan-14	2.4	0.6	1.5	0.5	3.6	0.9	1.1	1.2	1.2	2.0	0.9	0.9	1.0	0.9	1.5	0.9	21.1
Feb-14	2.2	0.6	1.6	0.6	3.5	0.8	1.0	1.2	1.1	1.8	0.9	0.6	1.0	0.9	1.6	0.9	20.4
Mar-14	2.2	0.6	1.6	0.6	4.5	1.0	1.2	1.3	1.0	1.7	0.9	0.9	0.9	0.9	1.5	1.0	21.9
Apr-14	2.3	0.6	1.4	0.6	2.6	0.9	1.0	1.2	1.0	1.6	0.9	0.7	1.1	1.3	1.4	1.0	19.5
May-14	2.1	0.5	1.6	0.6	2.1	0.9	1.5	1.3	0.9	1.8	0.8	0.6	1.0	1.2	1.2	1.0	19.4
Jun-14	2.2	0.5	1.9	0.7	2.0	0.9	1.0	1.2	0.9	1.9	1.2	0.8	0.9	2.0	1.1	1.1	20.4
Jul-14	2.5	0.4	1.9	0.8	1.5	1.7	1.0	1.5	0.8	2.1	1.0	1.0	1.1	2.0	1.0	1.2	21.5
Aug-14	2.3	0.4	2.2	0.7	1.5	1.0	1.0	1.6	0.8	2.1	1.1	0.8	1.0	2.1	1.2	1.2	21.0
Sep-14	1.4	0.4	2.1	0.6	2.0	1.0	1.5	1.2	0.9	2.1	1.2	1.0	1.0	2.3	0.9	1.2	20.9
Oct-14	2.6	0.3	2.3	0.5	1.7	1.0	1.4	1.2	1.0	2.3	1.1	0.9	0.9	2.1	1.0	1.0	21.4
Nov-14	2.5	0.3	2.5	0.5	1.8	0.6	1.4	1.1	0.9	2.2	1.1	0.5	0.9	2.1	1.3	1.1	20.9
Dec-14	2.4	0.3	2.5	0.6	1.8	1.0	1.1	1.5	1.1	2.3	1.1	0.7	1.2	2.0	1.2	0.9	21.9
Jan-15	2.1	0.2	2.2	0.7	2.2	1.2	1.2	1.5	1.3	2.3	1.0	0.5	1.2	1.8	1.3	0.9	21.5
Feb-15	2.8	0.2	2.6	0.7	2.5	1.1	1.3	1.6	1.5	2.2	1.0	0.7	1.4	1.8	1.2	1.0	23.6
Mar-15	1.7	0.2	2.5	0.8	3.3	0.1	1.5	1.7	1.8	2.0	1.0	0.9	1.4	0.4	1.2	0.9	21.4
Apr-15	1.6	0.2	2.5	0.9	5.4	1.0	1.3	1.4	1.6	1.9	1.0	0.8	1.3	1.8	1.4	1.1	25.2
May-15	1.7	0.3	2.6	0.9	3.5	1.2	1.2	1.8	1.6	1.7	1.0	0.8	1.3	1.9	1.4	1.0	23.8
Jun-15	0.5	0.2	2.7	0.8	3.1	1.2	1.1	1.6	1.7	1.9	0.8	0.6	1.1	1.7	1.5	1.3	21.8
Jul-15	1.5	0.3	2.6	0.8	3.0	1.2	1.5	1.3	1.5	1.8	0.8	0.8	1.2	1.6	1.7	1.3	22.9
Aug-15	1.7	0.3	2.4	0.8	3.1	1.1	1.0	1.3	1.4	1.7	0.9	0.6	1.4	1.8	1.5	1.3	22.2
Sep-15	1.7	0.3	2.1	0.8	2.7	1.0	7.4	1.5	1.4	1.8	0.8	0.9	1.2	1.7	1.4	0.9	27.5
Oct-15	1.6	0.3	2.3	0.7	2.6	0.9	1.2	1.3	1.4	1.6	1.0	0.7	1.3	1.9	1.3	1.3	21.3
Nov-15	1.6	0.3	2.2	0.6	1.8	0.9	1.0	1.0	1.3	1.6	0.9	0.7	1.7	1.7	1.1	1.2	19.6
Dec-15	1.8	0.4	3.7	0.6	1.4	0.9	1.5	1.6	1.3	1.4	0.9	0.9	1.3	1.4	1.1	1.5	21.7
2015 Actual	1.7	0.3	2.5	0.8	2.9	1.0	1.8	1.5	1.5	1.8	0.9	0.7	1.3	1.6	1.3	1.1	22.7

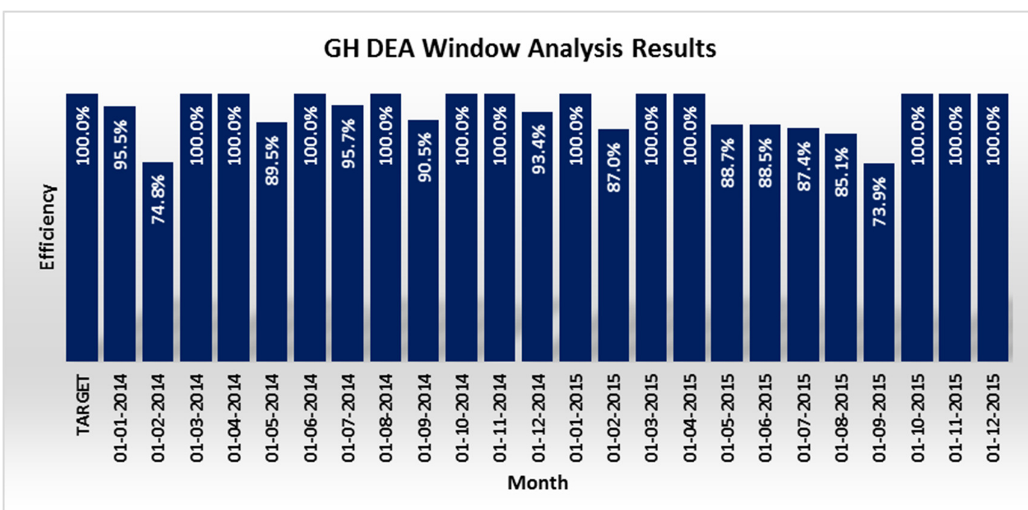
APPENDIX C: WINDOW ANALYSIS RESULTS

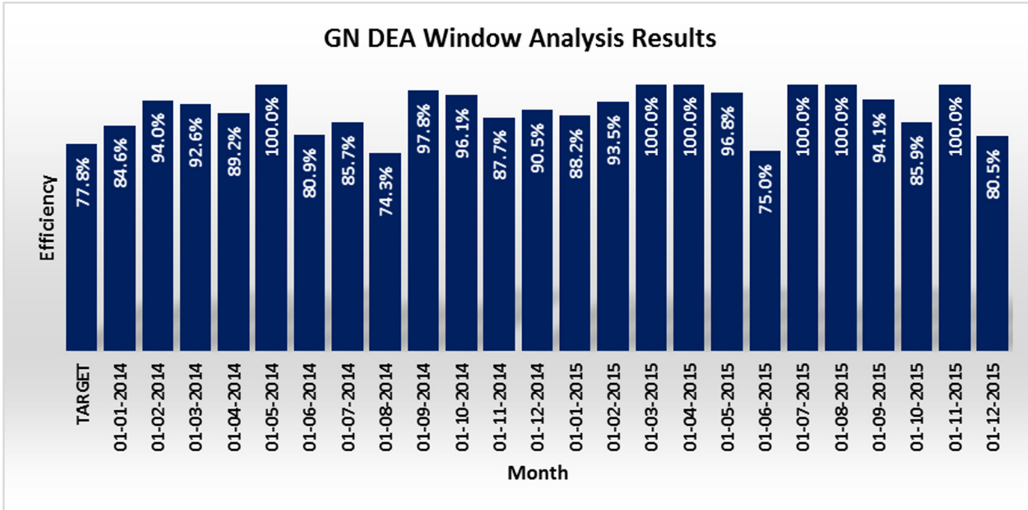


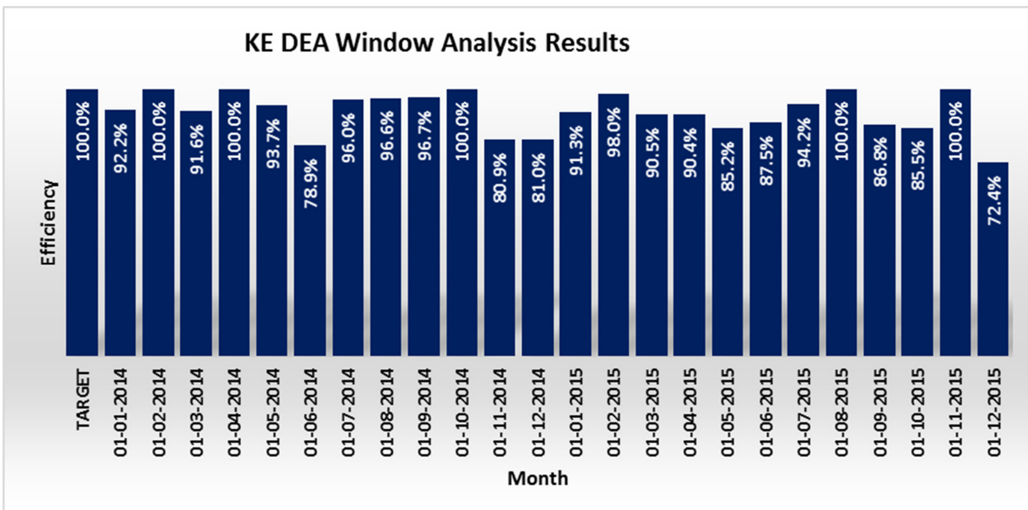


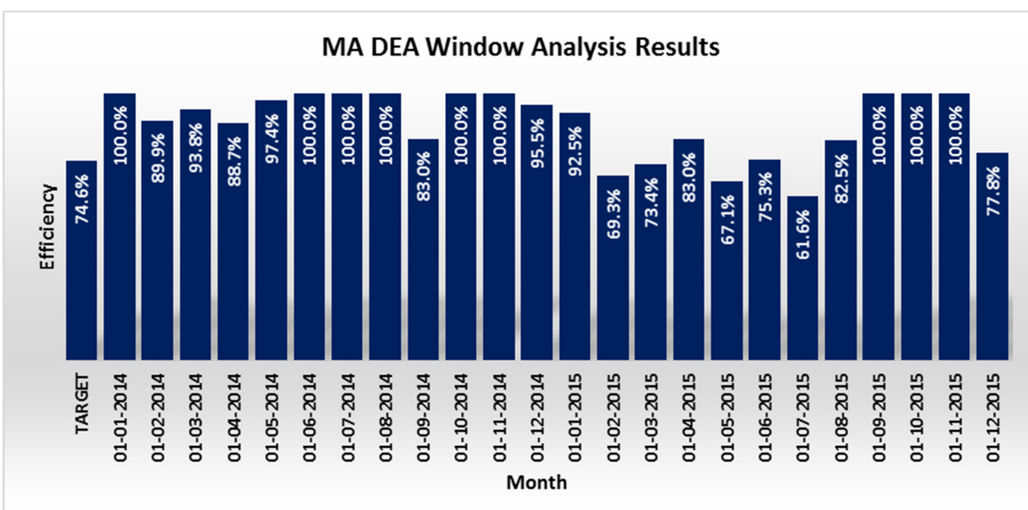

CI DEA Window Analysis Results
Efficiency
Month
TARGET 100.0%
01-01-2014 100.0%
01-02-2014 84.9%
01-03-2014 100.0%
01-04-2014 100.0%
01-05-2014 100.0%
01-06-2014 83.9%
01-07-2014 94.2%
01-08-2014 94.2%
01-09-2014 78.0%
01-10-2014 81.9%
01-11-2014 88.7%
01-12-2014 83.9%
01-01-2015 79.9%
01-02-2015 81.4%
01-03-2015 83.1%
01-04-2015 89.7%
01-05-2015 80.4%
01-06-2015 87.9%
01-07-2015 84.0%
01-08-2015 100.0%
01-09-2015 100.0%
01-10-2015 89.9%
01-11-2015 94.7%
01-12-2015 100.0%

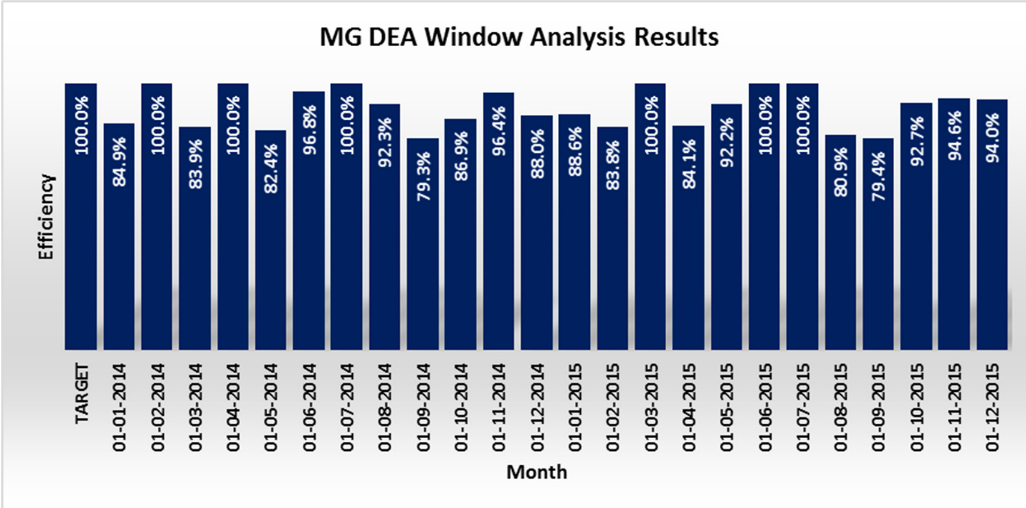

CV DEA Window Analysis Results
Efficiency
Month
TARGET 96.9%
01-01-2014 88.7%
01-02-2014 100.0%
01-03-2014 100.0%
01-04-2014 99.8%
01-05-2014 92.1%
01-06-2014 90.0%
01-07-2014 100.0%
01-08-2014 92.9%
01-09-2014 100.0%
01-10-2014 100.0%
01-11-2014 100.0%
01-12-2014 99.8%
01-01-2015 50.0%
01-02-2015 55.4%
01-03-2015 46.7%
01-04-2015 52.3%
01-05-2015 45.3%
01-06-2015 34.3%
01-07-2015 48.1%
01-08-2015 37.1%
01-09-2015 48.6%
01-10-2015 60.1%
01-11-2015 64.3%
01-12-2015 55.3%

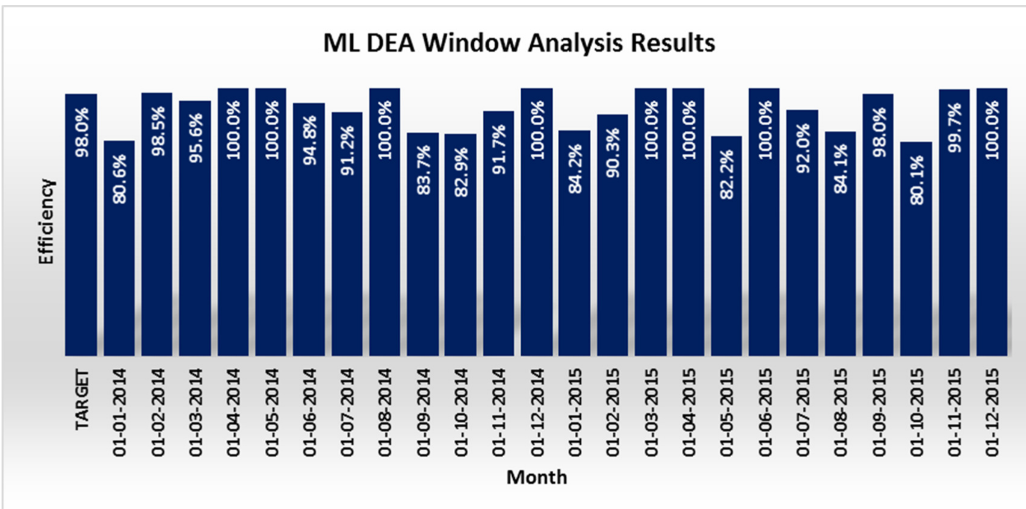

GH DEA Window Analysis Results
Efficiency
Month
TARGET 100.0%
01-01-2014 95.5%
01-02-2014 74.8%
01-03-2014 100.0%
01-04-2014 100.0%
01-05-2014 89.5%
01-06-2014 100.0%
01-07-2014 95.7%
01-08-2014 100.0%
01-09-2014 90.5%
01-10-2014 100.0%
01-11-2014 100.0%
01-12-2014 93.4%
01-01-2015 100.0%
01-02-2015 87.0%
01-03-2015 100.0%
01-04-2015 100.0%
01-05-2015 88.7%
01-06-2015 88.5%
01-07-2015 87.4%
01-08-2015 85.1%
01-09-2015 73.9%
01-10-2015 100.0%
01-11-2015 100.0%
01-12-2015 100.0%

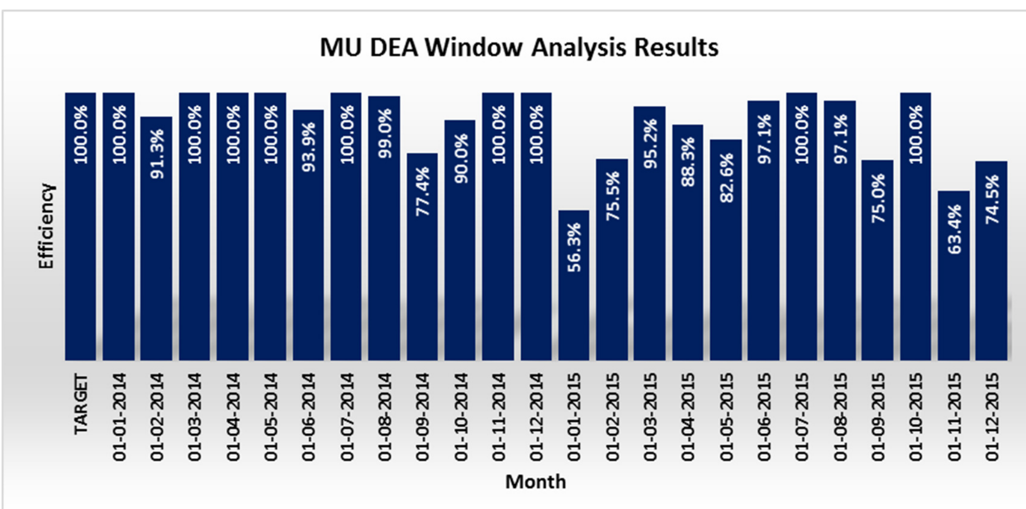

GN DEA Window Analysis Results
Efficiency
Month
77.8%
84.6%
94.0%
92.6%
89.2%
100.0%
80.9%
85.7%
74.3%
97.8%
96.1%
87.7%
90.5%
88.2%
93.5%
100.0%
100.0%
96.8%
75.0%
100.0%
100.0%
94.1%
85.9%
100.0%
80.5%
TARGET
01-01-2014
01-02-2014
01-03-2014
01-04-2014
01-05-2014
01-06-2014
01-07-2014
01-08-2014
01-09-2014
01-10-2014
01-11-2014
01-12-2014
01-01-2015
01-02-2015
01-03-2015
01-04-2015
01-05-2015
01-06-2015
01-07-2015
01-08-2015
01-09-2015
01-10-2015
01-11-2015
01-12-2015

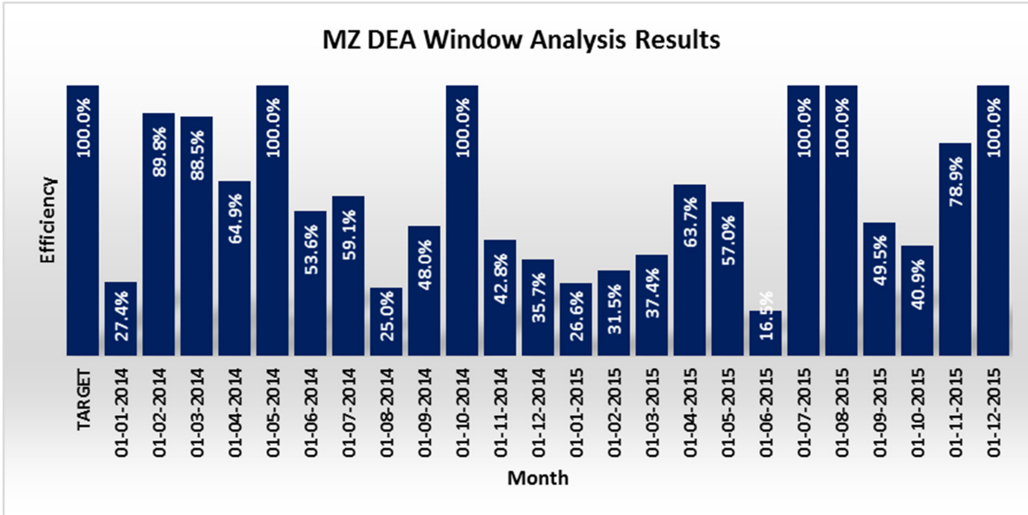

KE DEA Window Analysis Results
Efficiency
Month
100.0%
92.2%
100.0%
91.6%
100.0%
93.7%
78.9%
96.0%
96.6%
96.7%
100.0%
80.9%
81.0%
91.3%
98.0%
90.5%
90.4%
85.2%
87.5%
94.2%
100.0%
86.8%
85.5%
100.0%
72.4%
TARGET
01-01-2014
01-02-2014
01-03-2014
01-04-2014
01-05-2014
01-06-2014
01-07-2014
01-08-2014
01-09-2014
01-10-2014
01-11-2014
01-12-2014
01-01-2015
01-02-2015
01-03-2015
01-04-2015
01-05-2015
01-06-2015
01-07-2015
01-08-2015
01-09-2015
01-10-2015
01-11-2015
01-12-2015

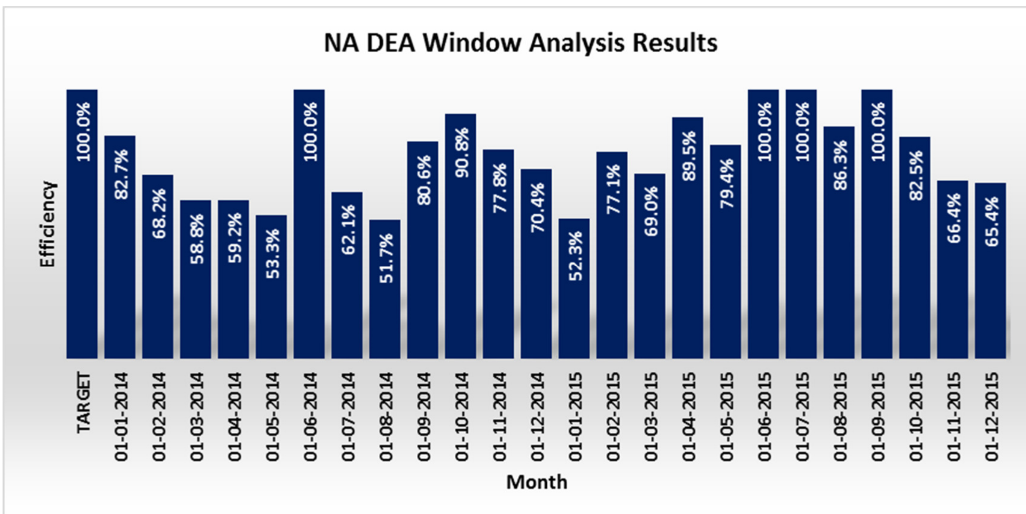

MA DEA Window Analysis Results
Efficiency
Month
74.6%
100.0%
89.9%
93.8%
88.7%
97.4%
100.0%
100.0%
100.0%
83.0%
100.0%
100.0%
95.5%
92.5%
69.3%
73.4%
83.0%
67.1%
75.3%
61.6%
82.5%
100.0%
100.0%
100.0%
77.8%
TARGET
01-01-2014
01-02-2014
01-03-2014
01-04-2014
01-05-2014
01-06-2014
01-07-2014
01-08-2014
01-09-2014
01-10-2014
01-11-2014
01-12-2014
01-01-2015
01-02-2015
01-03-2015
01-04-2015
01-05-2015
01-06-2015
01-07-2015
01-08-2015
01-09-2015
01-10-2015
01-11-2015
01-12-2015

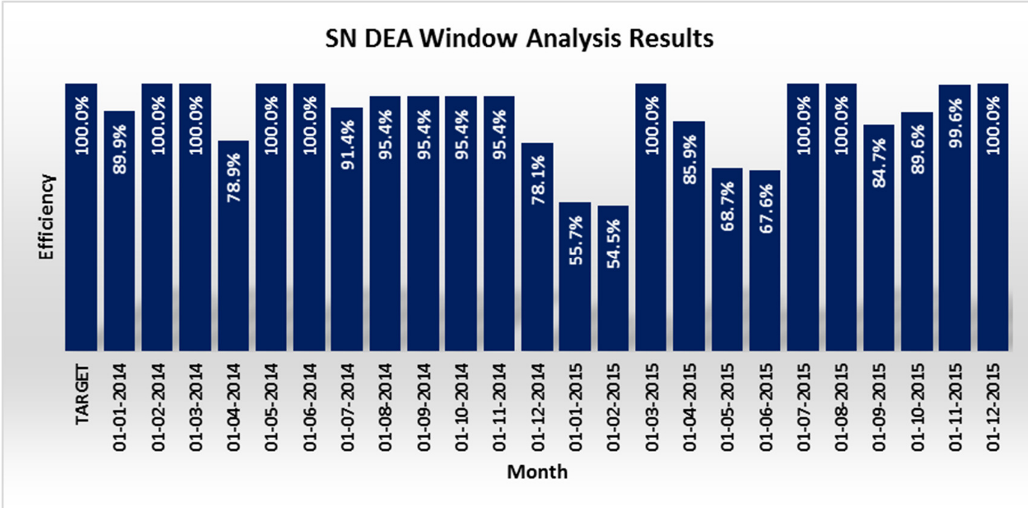

MG DEA Window Analysis Results
Efficiency
Month
TARGET 100.0%
01-01-2014 84.9%
01-02-2014 100.0%
01-03-2014 83.9%
01-04-2014 100.0%
01-05-2014 82.4%
01-06-2014 96.8%
01-07-2014 100.0%
01-08-2014 92.3%
01-09-2014 79.3%
01-10-2014 86.9%
01-11-2014 96.4%
01-12-2014 88.0%
01-01-2015 88.6%
01-02-2015 83.8%
01-03-2015 100.0%
01-04-2015 84.1%
01-05-2015 92.2%
01-06-2015 100.0%
01-07-2015 100.0%
01-08-2015 80.9%
01-09-2015 79.4%
01-10-2015 92.7%
01-11-2015 94.6%
01-12-2015 94.0%

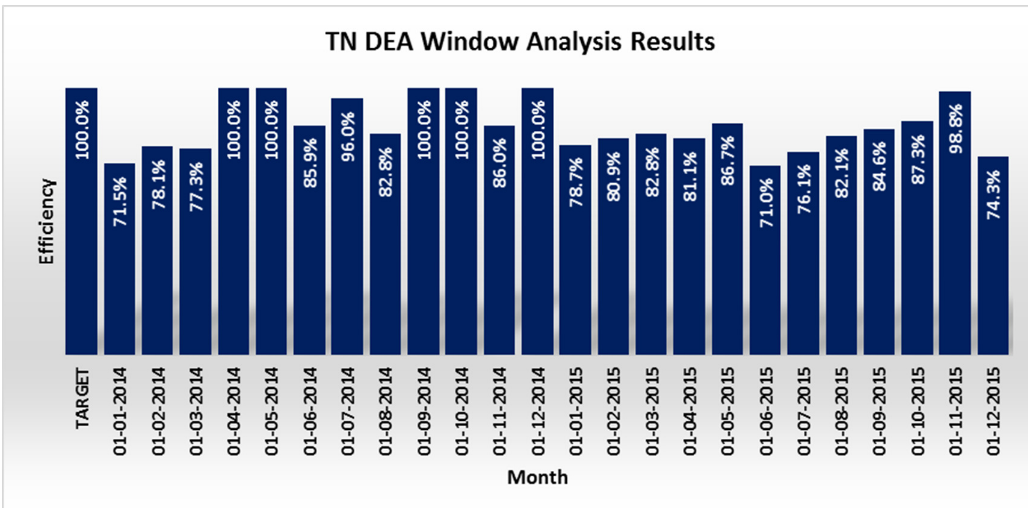

ML DEA Window Analysis Results
Efficiency
Month
TARGET 98.0%
01-01-2014 80.6%
01-02-2014 98.5%
01-03-2014 95.6%
01-04-2014 100.0%
01-05-2014 100.0%
01-06-2014 94.8%
01-07-2014 91.2%
01-08-2014 100.0%
01-09-2014 83.7%
01-10-2014 82.9%
01-11-2014 91.7%
01-12-2014 100.0%
01-01-2015 84.2%
01-02-2015 90.3%
01-03-2015 100.0%
01-04-2015 100.0%
01-05-2015 82.2%
01-06-2015 100.0%
01-07-2015 92.0%
01-08-2015 84.1%
01-09-2015 98.0%
01-10-2015 80.1%
01-11-2015 99.7%
01-12-2015 100.0%

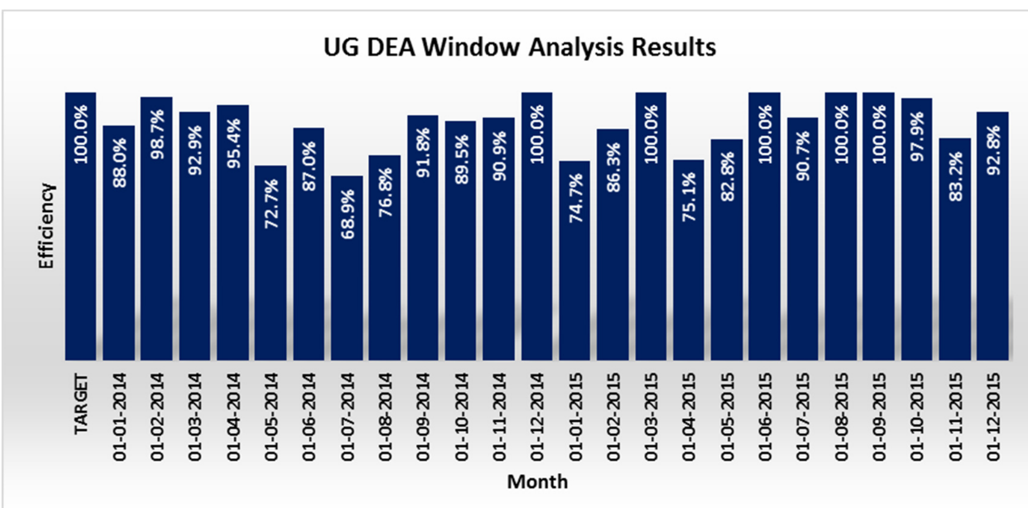

MU DEA Window Analysis Results
Efficiency
Month
TARGET 100.0%
01-01-2014 100.0%
01-02-2014 91.3%
01-03-2014 100.0%
01-04-2014 100.0%
01-05-2014 100.0%
01-06-2014 93.9%
01-07-2014 100.0%
01-08-2014 99.0%
01-09-2014 77.4%
01-10-2014 90.0%
01-11-2014 100.0%
01-12-2014 100.0%
01-01-2015 56.3%
01-02-2015 75.5%
01-03-2015 95.2%
01-04-2015 88.3%
01-05-2015 82.6%
01-06-2015 97.1%
01-07-2015 100.0%
01-08-2015 97.1%
01-09-2015 75.0%
01-10-2015 100.0%
01-11-2015 63.4%
01-12-2015 74.5%


MZ DEA Window Analysis Results
Efficiency
Month
TARGET 100.0%
01-01-2014 27.4%
01-02-2014 89.8%
01-03-2014 88.5%
01-04-2014 64.9%
01-05-2014 100.0%
01-06-2014 53.6%
01-07-2014 59.1%
01-08-2014 25.0%
01-09-2014 48.0%
01-10-2014 100.0%
01-11-2014 42.8%
01-12-2014 35.7%
01-01-2015 26.6%
01-02-2015 31.5%
01-03-2015 37.4%
01-04-2015 63.7%
01-05-2015 57.0%
01-06-2015 16.5%
01-07-2015 100.0%
01-08-2015 100.0%
01-09-2015 49.5%
01-10-2015 40.9%
01-11-2015 78.9%
01-12-2015 100.0%

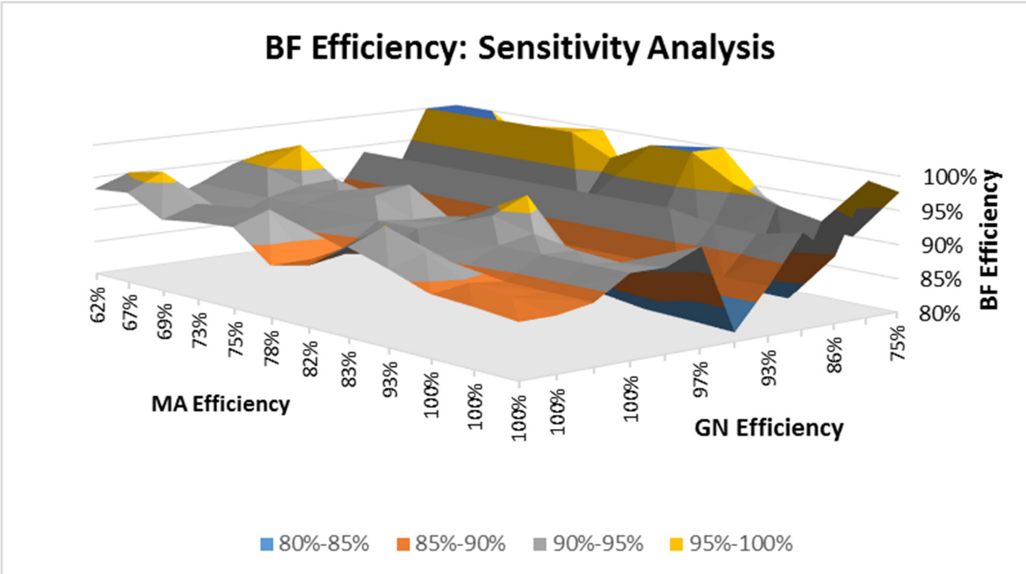

NA DEA Window Analysis Results
Efficiency
Month
TARGET 100.0%
01-01-2014 82.7%
01-02-2014 68.2%
01-03-2014 58.8%
01-04-2014 59.2%
01-05-2014 53.3%
01-06-2014 100.0%
01-07-2014 62.1%
01-08-2014 51.7%
01-09-2014 80.6%
01-10-2014 90.8%
01-11-2014 77.8%
01-12-2014 70.4%
01-01-2015 52.3%
01-02-2015 77.1%
01-03-2015 69.0%
01-04-2015 89.5%
01-05-2015 79.4%
01-06-2015 100.0%
01-07-2015 100.0%
01-08-2015 86.3%
01-09-2015 100.0%
01-10-2015 82.5%
01-11-2015 66.4%
01-12-2015 65.4%

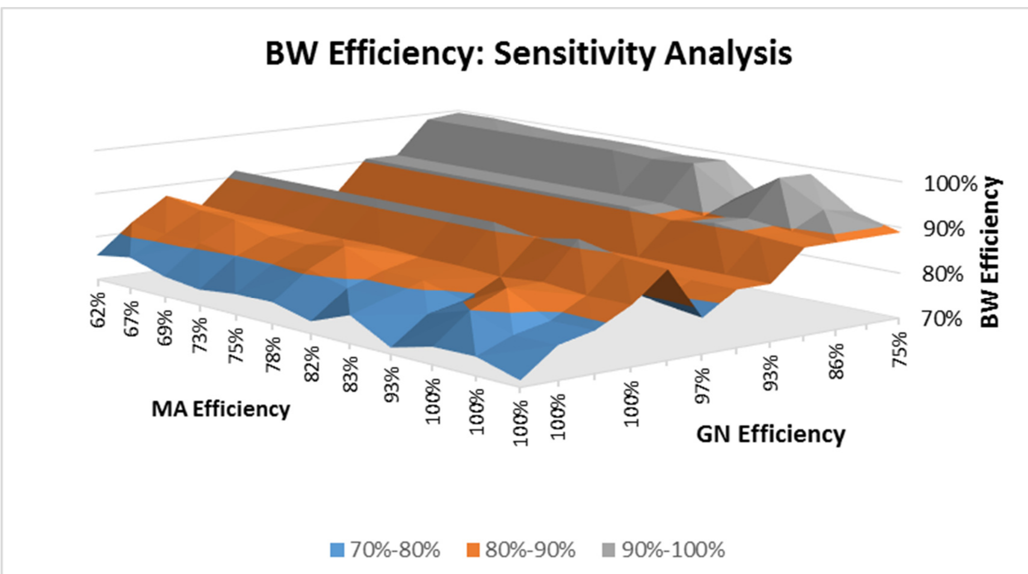

SN DEA Window Analysis Results
Efficiency
100.0%
89.9%
100.0%
100.0%
78.9%
100.0%
100.0%
91.4%
95.4%
95.4%
95.4%
95.4%
78.1%
55.7%
54.5%
100.0%
85.9%
68.7%
67.6%
100.0%
100.0%
84.7%
89.6%
99.6%
100.0%
TARGET
01-01-2014
01-02-2014
01-03-2014
01-04-2014
01-05-2014
01-06-2014
01-07-2014
01-08-2014
01-09-2014
01-10-2014
01-11-2014
01-12-2014
01-01-2015
01-02-2015
01-03-2015
01-04-2015
01-05-2015
01-06-2015
01-07-2015
01-08-2015
01-09-2015
01-10-2015
01-11-2015
01-12-2015
Month

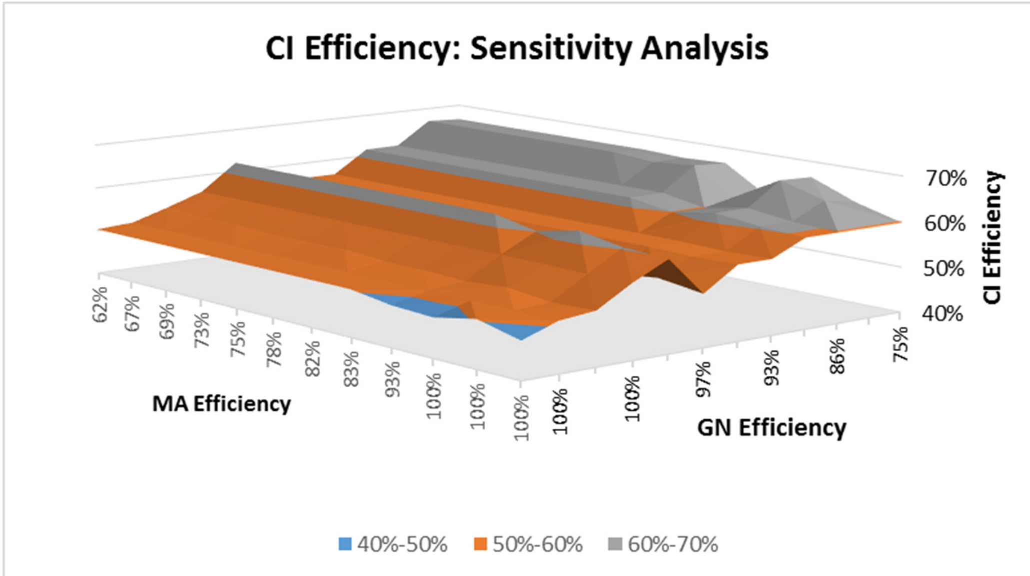

TN DEA Window Analysis Results
Efficiency
100.0%
71.5%
78.1%
77.3%
100.0%
100.0%
85.9%
96.0%
82.8%
100.0%
100.0%
86.0%
100.0%
78.7%
80.9%
82.8%
81.1%
86.7%
71.0%
76.1%
82.1%
84.6%
87.3%
98.8%
74.3%
TARGET
01-01-2014
01-02-2014
01-03-2014
01-04-2014
01-05-2014
01-06-2014
01-07-2014
01-08-2014
01-09-2014
01-10-2014
01-11-2014
01-12-2014
01-01-2015
01-02-2015
01-03-2015
01-04-2015
01-05-2015
01-06-2015
01-07-2015
01-08-2015
01-09-2015
01-10-2015
01-11-2015
01-12-2015
Month

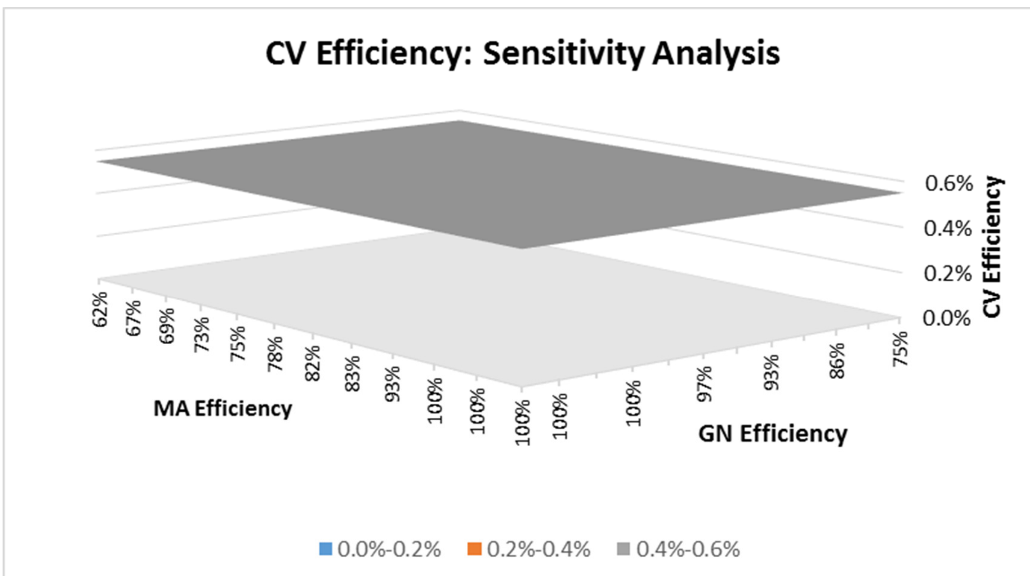

UG DEA Window Analysis Results
Efficiency
100.0%
88.0%
98.7%
92.9%
95.4%
72.7%
87.0%
68.9%
76.8%
91.8%
89.5%
90.9%
100.0%
74.7%
86.3%
100.0%
75.1%
82.8%
100.0%
90.7%
100.0%
100.0%
97.9%
83.2%
92.8%
TARGET
01-01-2014
01-02-2014
01-03-2014
01-04-2014
01-05-2014
01-06-2014
01-07-2014
01-08-2014
01-09-2014
01-10-2014
01-11-2014
01-12-2014
01-01-2015
01-02-2015
01-03-2015
01-04-2015
01-05-2015
01-06-2015
01-07-2015
01-08-2015
01-09-2015
01-10-2015
01-11-2015
01-12-2015
Month

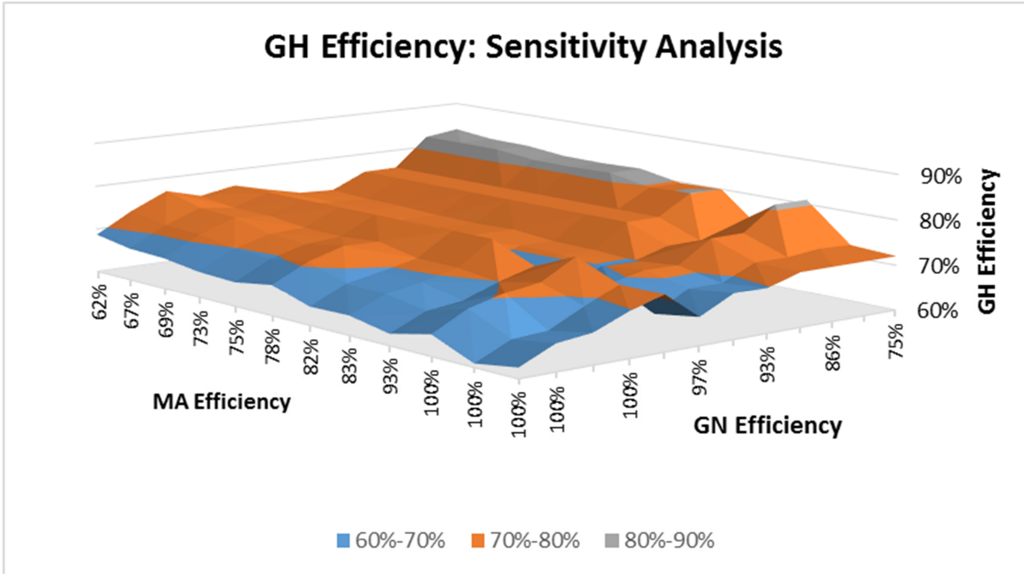
APPENDIX D: SENSITIVITY ANALYSIS RESULTS

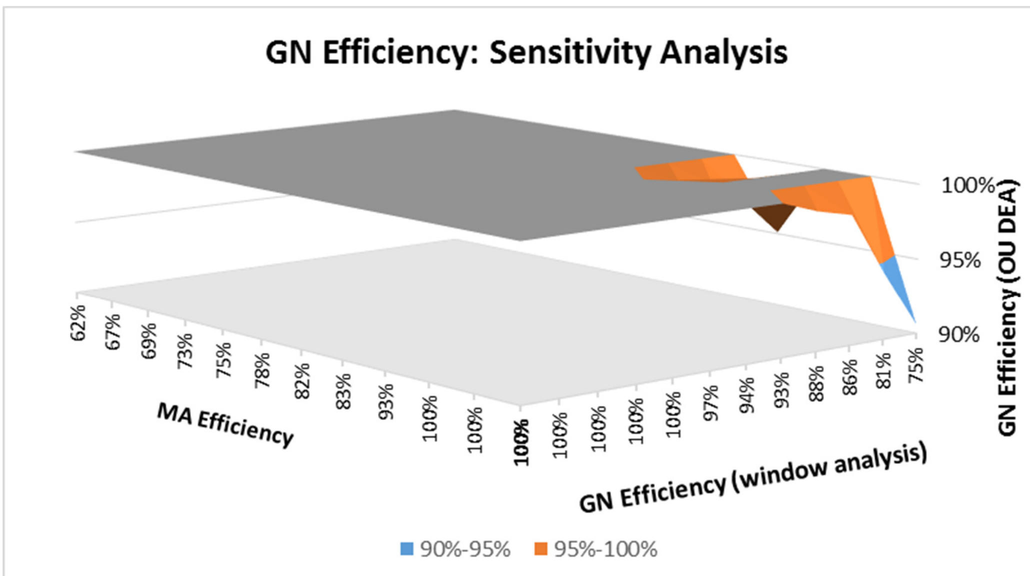


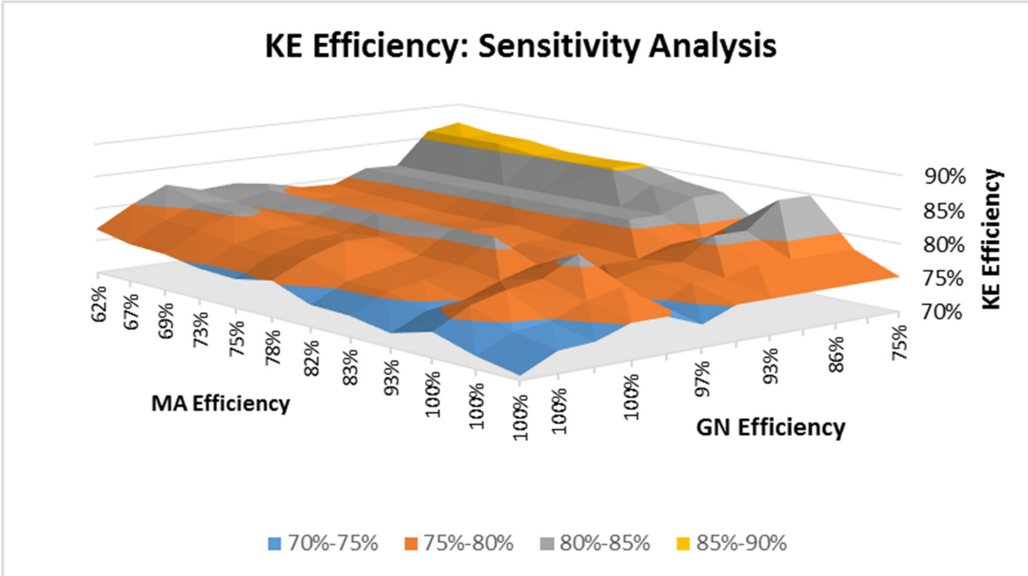


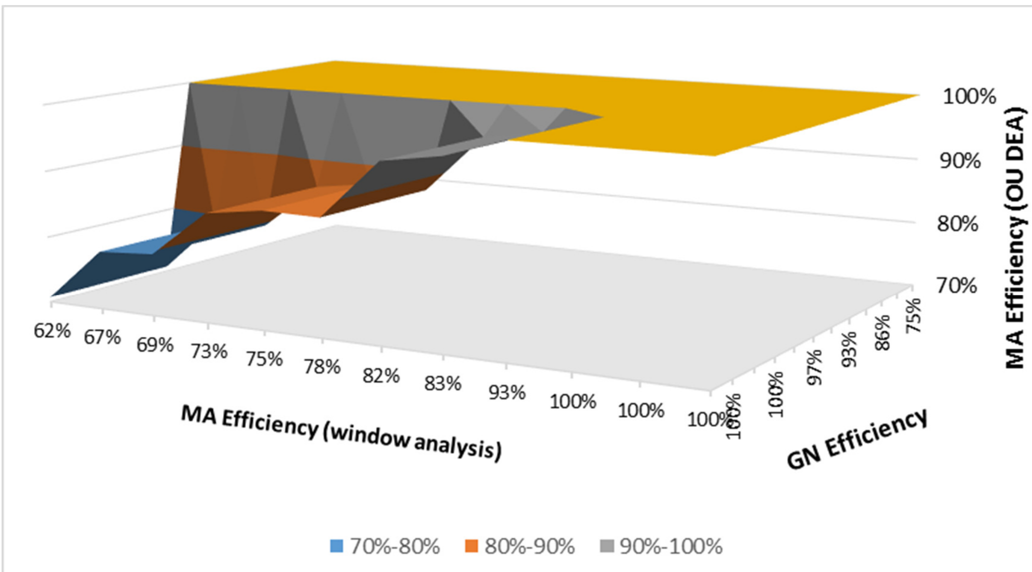

CI Efficiency: Sensitivity Analysis
70%
60%
50%
40%
CI Efficiency
62%
67%
69%
73%
75%
78%
82%
83%
93%
100%
100%
MA Efficiency
100%
100%
100%
97%
93%
86%
75%
GN Efficiency
40%-50%
50%-60%
60%-70%

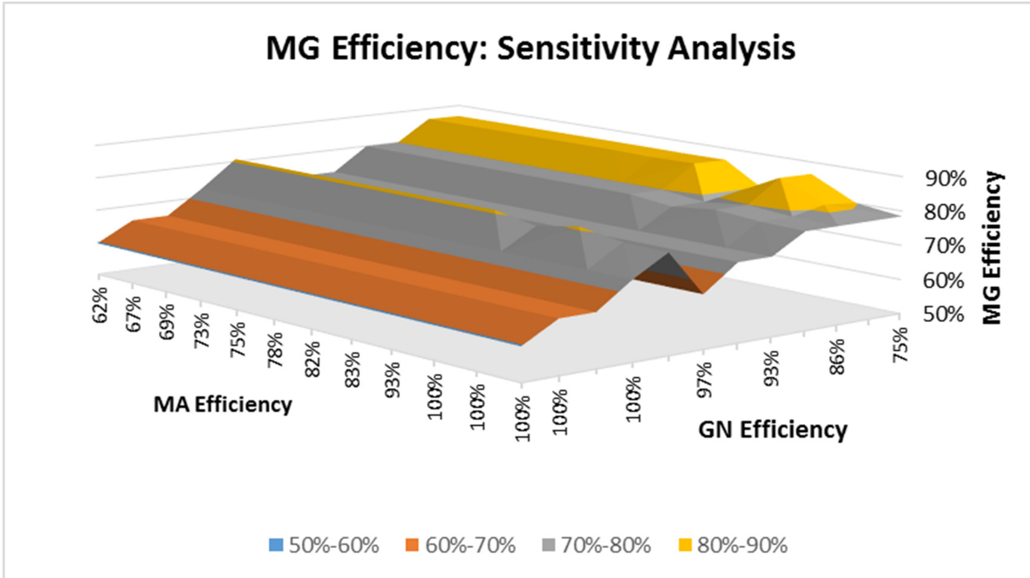

CV Efficiency: Sensitivity Analysis
0.6%
0.4%
0.2%
0.0%
CV Efficiency
62%
67%
69%
73%
75%
78%
82%
83%
93%
100%
100%
MA Efficiency
100%
100%
100%
97%
93%
86%
75%
GN Efficiency
0.0%-0.2%
0.2%-0.4%
0.4%-0.6%

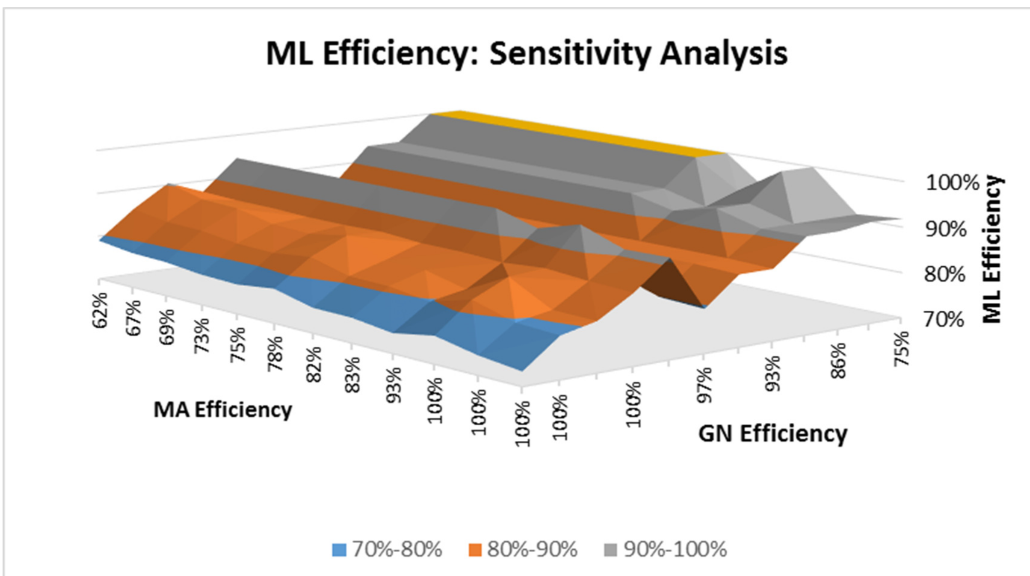

GH Efficiency: Sensitivity Analysis
90%
80%
70%
60%
GH Efficiency
62%
67%
69%
73%
75%
78%
82%
83%
93%
100%
100%
100%
100%
100%
97%
93%
86%
75%
MA Efficiency
GN Efficiency
60%-70%
70%-80%
80%-90%

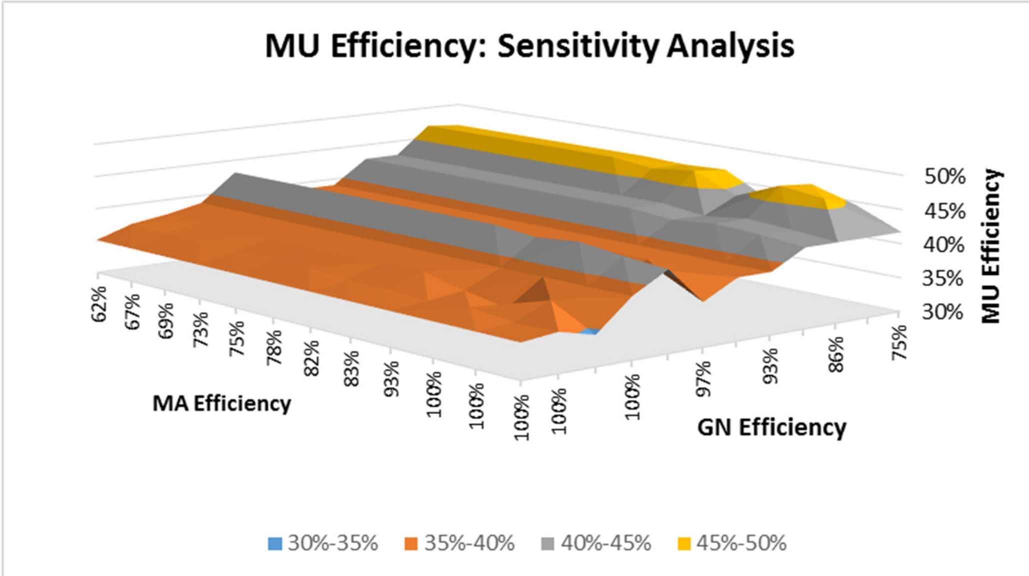

GN Efficiency: Sensitivity Analysis
100%
95%
90%
GN Efficiency (OU DEA)
62%
67%
69%
73%
75%
78%
82%
83%
93%
100%
100%
100%
100%
100%
100%
100%
97%
94%
93%
88%
86%
81%
75%
MA Efficiency
GN Efficiency (window analysis)
90%-95%
95%-100%

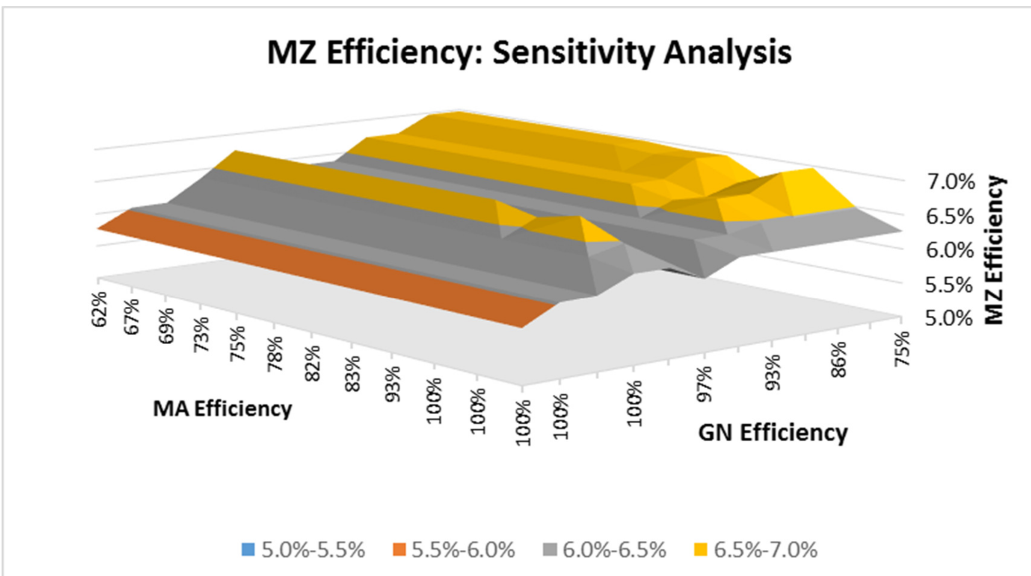

KE Efficiency: Sensitivity Analysis
90%
85%
80%
75%
70%
KE Efficiency
62%
67%
69%
73%
75%
78%
82%
83%
93%
100%
100%
100%
MA Efficiency
100%
100%
97%
93%
86%
75%
GN Efficiency
70%-75%
75%-80%
80%-85%
85%-90%

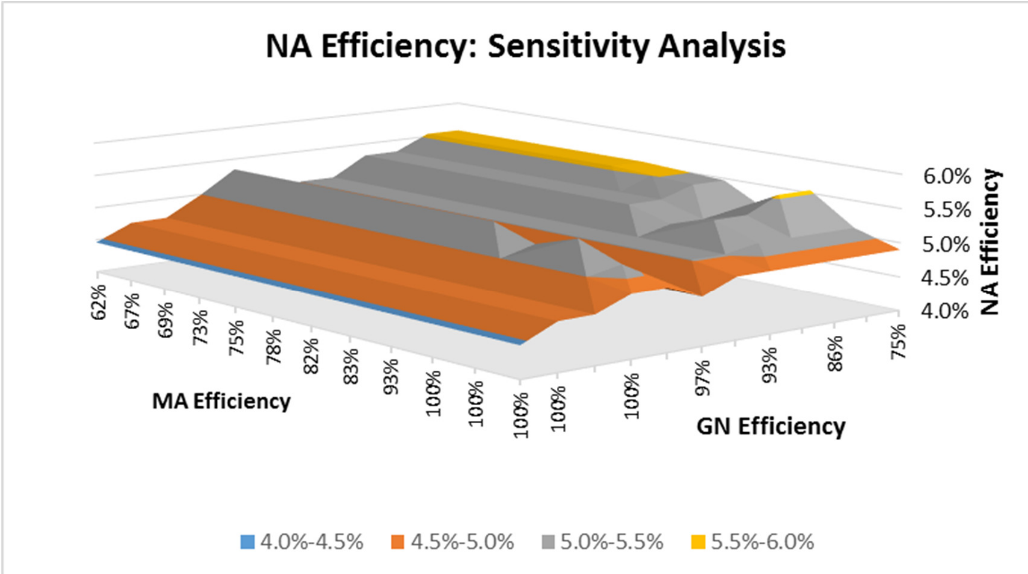

100%
90%
80%
70%
MA Efficiency (OU DEA)
62%
67%
69%
73%
75%
78%
82%
83%
93%
100%
100%
100%
MA Efficiency (window analysis)
100%
100%
97%
93%
86%
75%
GN Efficiency
70%-80%
80%-90%
90%-100%

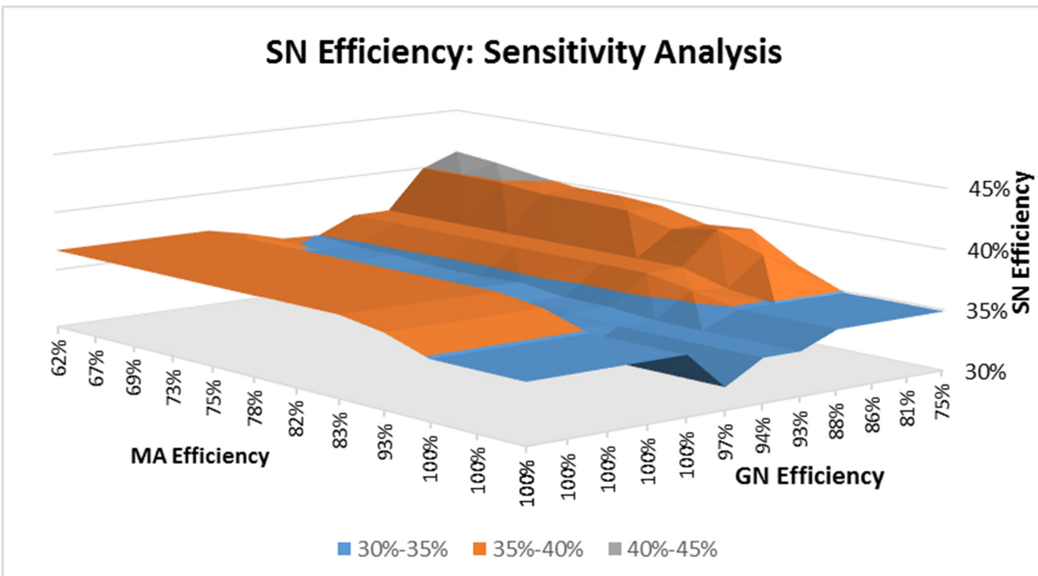

MG Efficiency: Sensitivity Analysis
90%
80%
70%
60%
50%
MG Efficiency
62%
67%
69%
73%
75%
78%
82%
83%
93%
100%
100%
100%
MA Efficiency
100%
100%
97%
93%
86%
75%
GN Efficiency
50%-60%
60%-70%
70%-80%
80%-90%

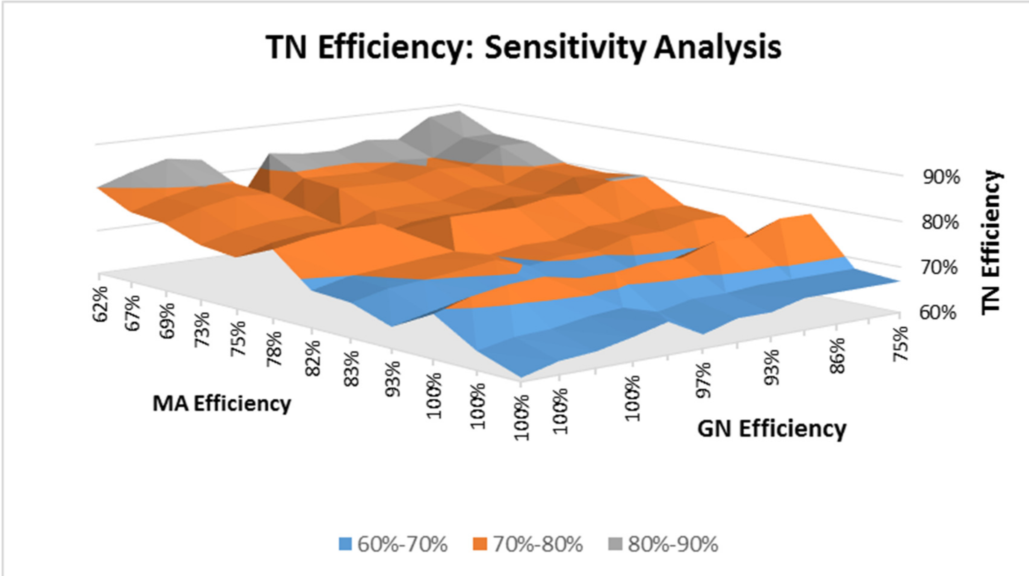

ML Efficiency: Sensitivity Analysis
100%
90%
80%
70%
ML Efficiency
62%
67%
69%
73%
75%
78%
82%
83%
93%
100%
100%
100%
MA Efficiency
100%
100%
97%
93%
86%
75%
GN Efficiency
70%-80%
80%-90%
90%-100%

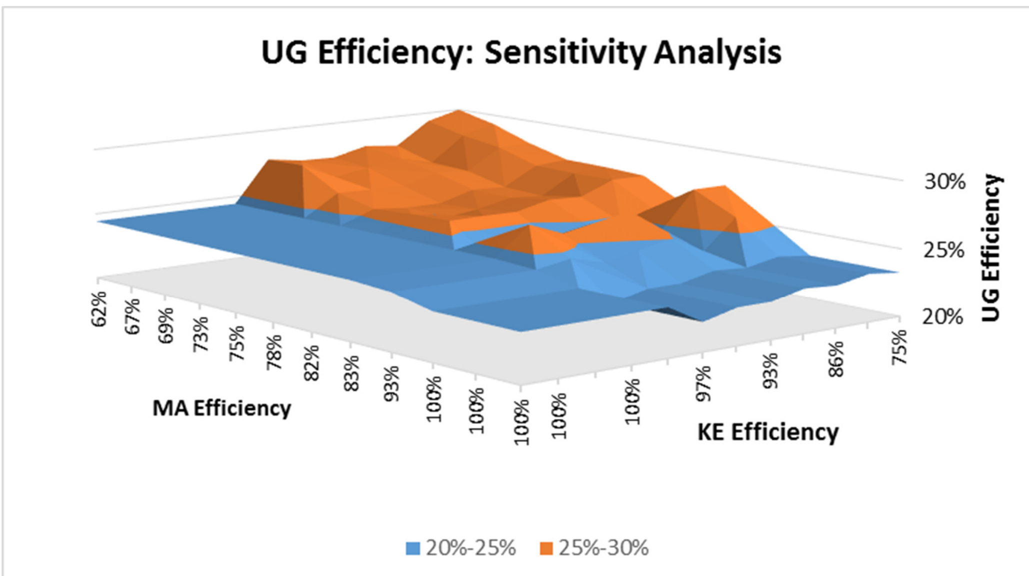

MU Efficiency: Sensitivity Analysis
50%
45%
40%
35%
30%
MU Efficiency
62%
67%
69%
73%
75%
78%
82%
83%
93%
100%
100%
100%
100%
100%
97%
93%
86%
75%
MA Efficiency
GN Efficiency
30%-35%
35%-40%
40%-45%
45%-50%


MZ Efficiency: Sensitivity Analysis
7.0%
6.5%
6.0%
5.5%
5.0%
MZ Efficiency
62%
67%
69%
73%
75%
78%
82%
83%
93%
100%
100%
100%
100%
100%
97%
93%
86%
75%
MA Efficiency
GN Efficiency
5.0%-5.5%
5.5%-6.0%
6.0%-6.5%
6.5%-7.0%


NA Efficiency: Sensitivity Analysis
6.0%
5.5%
5.0%
4.5%
4.0%
NA Efficiency
62%
67%
69%
73%
75%
78%
82%
83%
93%
100%
100%
MA Efficiency
100%
100%
100%
97%
93%
86%
75%
GN Efficiency
4.0%-4.5%
4.5%-5.0%
5.0%-5.5%
5.5%-6.0%


SN Efficiency: Sensitivity Analysis
45%
40%
35%
30%
SN Efficiency
62%
67%
69%
73%
75%
78%
82%
83%
93%
100%
100%
MA Efficiency
100%
100%
100%
100%
100%
97%
94%
93%
88%
86%
81%
75%
GN Efficiency
30%-35%
35%-40%
40%-45%


TN Efficiency: Sensitivity Analysis
90%
80%
70%
60%
TN Efficiency
62%
67%
69%
73%
75%
78%
82%
83%
93%
100%
100%
100%
MA Efficiency
100%
100%
97%
93%
86%
75%
GN Efficiency
60%-70%
70%-80%
80%-90%


UG Efficiency: Sensitivity Analysis
30%
25%
20%
UG Efficiency
62%
67%
69%
73%
75%
78%
82%
83%
93%
100%
100%
100%
MA Efficiency
100%
100%
97%
93%
86%
75%
KE Efficiency
20%-25%
25%-30%