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# Engineering change management as a process enabler for collaborative product design

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## Abstract

Organisation faced with competitive market pressures and those that are looking at sustaining their market position may adopt collaborative product design as a strategy to improve quality, increase market share, increase efficiencies and reduce the time to market for their products. Conversely, in a design environment engineering changes are unavoidable and need to be effectively coordinated because they may become costly for a company in product recalls and reputational damage. They can however be viewed as a cost benefit as contributors to optimisation of product quality.

In this study, engineering changes were examined as enablers to collaborative product design where the study was undertaken in the land systems sector of defence in South Africa. The sector is faced with defence cuts resulting in direct and indirect job losses across the supply chain. An exploratory study was conducted where the constraints to design performance were evaluated. The applicability of the data and process orientated information exchange models were explored on the extent they influence the speed of engineering changes. The outcome was a model that can be used as an evaluation and decision making tool for companies conducting collaborative strategy with emphasis on engineering changes and information flow.

## Keywords

Collaborative product design
Engineering change management
Information flow
Defence industry
Africa

## Declaration

I declare that this research project is my own work. It is submitted in partial fulfilment of the requirements for the degree of Master of Business Administration at the Gordon Institute of Business Science, University of Pretoria. It has not been submitted before for any degree or examination in any other University. I further declare that I have obtained the necessary authorisation and consent to carry out this research.

Name Tebogo Peter Chauke

Signature ................................

Date 11 November 2013

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# Chapter 1: Introduction to Research Problem

## 1.1 Introduction

Defence cuts due to the recent global financial crisis and the planned withdrawal of the allied forces from Iraq and Afghanistan have brought pressure on defence contractors worldwide (National Association of Manufacturers, n.d.). Industry outlook reports on global aerospace and defence (A&D) sector projects, highlight that the global defence sector is expected to see continued declines in revenue, lower returns on invested capital, as well as margin contraction for many defence industry companies (Deloitte Touche Tohmatsu Limited Global Manufacturing Industry group, 2013; South African Department of Defence, 2012). These defence cuts will result in direct job losses for the defence contractors and indirectly affect employment levels of firms that supply defence contractors. What is also notable is that these losses in employment will be felt in other industries, including business services, transportation and the mining sectors (National Association of Manufacturers, n.d.). In 1988, Armscor, the South African defence acquisition company, had a subcontracting network of about 100,000 workers which represented approximately 8 percent of the total of South Africa's industrial employment (Rogerson, 1990). Although this figure is outdated and it may have been reduced drastically over the years to date, the point is, the survival of defence contractors in South Africa is also important to the economy.

Companies may choose to respond to this dynamic environment by increasingly adopting collaborative models to drive growth when faced with global competitive pressures (Hung, Chang, Yen, Kang, & Kuo, 2011; Silverstone, Wallis, & Mindrum, 2012). Martzall (2006) has shown that to stay ahead of competitors and to sustain a competitive edge, companies are constantly seeking innovative ways to compete and that may include collaborative product design (CPD). Collaboration models allow companies to build stronger relationships across the supply chain by making use of workflows and collections of software applications to design a product (Hung et al., 2011; Shiau, 2009). However, Silverstone et al. (2012) argued that to make these cross enterprise collaborations work, coordinated efforts on a range of issues will be required. These issues include organisational fit, inter-organisational trust, integration and alignment of business processes and having the competence to effectively deal with change (Hung et al., 2011; Martzall, 2006; Silverstone et al., 2012).

In the land systems sector of the defence industry where this research project was undertaken, it was found that defence contractors need to clearly understand the requirements of their customers which are then translated into business processes. For example, a survey conducted by Defence IQ's Armoured Vehicles 2012 report stated that Asian customers do not see the threat of Improvised Explosive Devices (IEDs) as a pressing issue as much as the West like America and Europe, which are in combat situations in Iraq and Afghanistan (Elwell, 2012). This means that defence contractors will need to supply vehicles which may have similar baselines or platforms, but which will be customised for different customers. These customisations and modifications may take the form of engineering changes (EC) to a range of products within the portfolio of the vehicle manufacturer to cater for the different markets, customer requests, technology improvements, legislative requirements, cost savings, manufacturing led improvements and design errors (Wasmer, Staub, & Vroom, 2011). For example, Burns (2013) reported that in Afghanistan, insurgents are generally using large improvised explosives which have caused damage to vehicles and death to soldiers. This illustrates the need to review the designs to meet evolving environments and customer needs. This review process is usually conducted in a structured approach by means of engineering change management (ECM) processes.

According to Wasmer et al. (2011), changes to engineering products are unavoidable and are a reflection of the learning process in an organisation. They further stated that product changes in a collaborative environment may require effective cross enterprise communication about agreements, data formats as well as orderly procedures for efficient communication between the stakeholders in a supply chain (Wasmer et al., 2011). This is also part of the issue that Reddi and Moon (2011) and

Silverstone et al. (2012) suggested about a need for cross enterprise processes like ECM to be effectively coordinated - especially when enterprises are designing products collaboratively in order to remain competitive. Wasmer et al. (2011) found that if EC are not adequately managed, they may prove to be costly for a company in terms of quality pitfalls, product recalls, retrofit actions and reputational damage. Conversely, EC can be viewed as opportunities to remain competitive, as contributors to optimisation of product quality, and as a means to reduce overall risk for a company (Reddi & Moon, 2011; Wasmer et al., 2011).

Given the above context, this research project sought to investigate how information is relayed between companies that are engaged in a CPD when EC occur. How would these companies that may be facing issues such as inter-organisational trust and organisation alignments, integrate and align their business processes to enable them to share information with respect to EC? How then, should EC be managed in a CPD environment as an enabler for design performance? Design performance in this context is based on five attributes: functionality, form, fitness, time to market, and cost. The objective of this study was thus to determine the extent to which ECM affects design performance in a CPD by analysing the land systems sector of defence in South Africa.

## 1.2 Background to the Problem

The defence sector is characterised by being highly technologically driven and sensitive to rapid development of new technologies, which can have both positive and negative consequences for organisations. Secondly, the increased complexity of the burgeoning technological landscape in this sector has driven the creation of new manufacturing companies as well as support industries (Department of Defence, 2012). Furthermore, it is a highly capital intensive sector with large financial risks, making it a relevant sector to conduct this research project (South African Department of Defence, 2012).

Against the background of global defence cuts and contextualising it for South Africa, Adonisi and Scheepers (2013, p.3) stated that "The unfolding political and socio-economic changes coupled with the re-entry of South Africa into the international business arena have created new challenges for South African businesses. As the new political dispensation unfolds, business organisations have had to make profound changes in order to negotiate the tide of change, and to remain competitive". This statement is not only true for South Africa, but for other emerging markets where budget cuts mean that defence contractors globally may increase their sales efforts into new geographic markets, and those markets that are facing increasing threats to their national security. (Figure 10 in Appendix 1 shows that the global growth of armoured vehicles pivots towards Asia, the Middle East and Brazil (Elwell, 2013)).

If defence contractors in the developed world can increase their presence in new markets, they may ensure that they mitigate against aggressive competition in their home markets (Deloitte Touche Tohmatsu Limited Global Manufacturing Industry group, 2013). In South Africa, the arms producers which were protected and subsidised in the old dispensation are now faced with new challenges (Dunne & Haines, 2002); they had to become cost efficient and financially viable by evolving their strategies of designing and manufacturing to leverage core competencies in defence products and services (Bitzinger, 2003). This is evidence that defence companies in emerging markets may need to evolve their strategies and exploit new opportunities because of the threat of defence contractors from the developed markets.

Bitzinger (2003) identified transitional and readjustment strategies for these defence companies as teaming arrangements to co-develop and co-produce armaments with global defence contractors, establishment of joint-venture companies, and cross border mergers and acquisitions. Bitzinger (2003) and Dunne and Haines (2002) further added that South African defence contractors view cooperation or subcontracting as critical to their survival and thus they positioned themselves as niche players with expertise in systems integration, programme management and customisation. They have been regarded as natural partners in collaborative programmes (Bitzinger, 2003), which is another reason this industry was chosen for this research project.

Chen, Chen and Chu (2008 p.395) stated that CPD which can be as a result of teaming arrangements, joint ventures or mergers “is considered as one of the most promising business strategies for enterprises to use in addressing global competition”. In their study they designed a structured methodology for developing engineering knowledge management systems for organisations involved in CPD, with the aim of increasing product development capability and quality, and reducing cycle times and costs (Chen et al., 2008). Their methodology was relevant to this research project because of some of the common themes that include flexibility of systems and platform cooperativeness that are useful when interacting with collaborative partners.

## 1.3 Problem Definition

According to Christopher (2000), companies are faced with turbulent and volatile markets where product life-cycles have shortened. These, coupled with global economic and competitive forces, create additional uncertainty for companies. Within this context, companies need to able to meet the evolving demands of customers for customised products within a specific time frame. In such a turbulent environment, launching products faster than the competition assists in gaining larger market share (Wang & Chen, 2012). According to Shiau (2009), CPD is a business strategy that enables members of a supply chain to work together to design a product and meet evolving customer needs. Companies in the South African defence sector realised this need and there is a resurgence within the sector to increase collaboration, as stated by the South African Minister of Enterprise Malusi Gigaba (SA News, 2013).

Shiau (2009) has shown that earlier participation of vendors in the design process will lead to improvements in product quality and a reduction in development cycle times. CPD has been suggested to reduce development lead time, thus cost will also be reduced. It can therefore be inferred that companies are likely to share costs in a collaborative environment (economies of scale), which will be beneficial in a defence sector that is undergoing budget cuts yet experiencing increased demand for high quality products.

Shiau (2009) has found that as outsourcing and globalisation increase, so too have the number of design chain participants. This increased number of design chain participants is likely to lead to complexities in management of information, for example when there are product changes. With the evolving needs of customers and technological changes several design changes can be expected in a CPD. When these EC occur in a CPD environment, they require systems that can effectively manage these changes and communicate them to affected parties. This illustrates that for CPD to be successful there must be a strong link to sharing of information. Wasmer et al. (2011) have shown that a more effective and efficient ECM procedure seeks to ensure that issues regarding an existing product design are clearly defined and carefully evaluated. These product design issues include process reliability, processing speed, cost of EC, time to market, product functions, form and fitness, and are attributes of design performance.

Christopher (2000) stated that companies that are responsive to market needs are regarded as agile, and have flexibility as a key characteristic. The objective was to explore what challenges exist that may constrain companies from being agile according to the type of information flow model they adopted. It intended to determine the impact of information flow models in collaborative environments because of their direct relationship to a sustainable competitive advantage. The companies that were examined in this study were chosen because they supply their products to the South African market as well as to different export markets. They have a history of collaboration and they operate with supply chain partners that are both mature and immature. This also posed a dynamic collaborative element showcasing the complexities and innovativeness required to survive in this sector.

The ECM process is important because it influences product lead time, cost and productivity and also because it manages an organisation’s response to dynamic market conditions (Wasmer et al., 2011). However, its complexity increases dramatically when several companies are involved collaboratively (Reddi & Moon, 2011). A model was thus developed in this study that sought to address the issues faced by collaborative partners to integrate and align their business processes for effective information flow and sharing when faced with engineering changes. The relevance of this research project is towards the promotion of competitiveness in a global environment. Lastly, the research recommendations are relevant to both the academic and the business sector.

# Chapter 2: Literature Review

## 2.1 Introduction

The aim of this chapter is to present the related literature with regards to the research problem, which was put into context through the history of the defence sector in South Africa, including how collaboration evolved in this industry. Once the context was set, the research problems were reviewed and evaluated through the challenges of CPD and those of ECM.

## 2.2 Evolution of the South African defence industry

The aim is of this section is to review the evolution of the defence industry in South Africa to put the research into context. It will give an understanding of how collaboration has influenced the industry and how defence contractors undertake their operational decisions. Rogerson (1990) stated that attempts at military manufacturing in South Africa date back to the 1920s. Rogerson (1990) cited Pretorius (1986) in his article which found that collaboration between the state and private companies can be traced back to 1934, when the South African government called private companies to tender for construction of a small arms factory. Rogerson (1990) further stated that from 1936 to 1937, the state entered into a collaboration agreement with African Explosives and Chemical Industry (AECI), a subsidiary of the British concern Imperial Chemical Industries (I.C.I), for the production of cartridges and bullets. This move was the signal of what would happen later in the 1960s where there was extensive collaboration between the state and the private sector in South African military production (Rogerson, 1990).

Rogerson (1990) also found that the War Supplies Board was created in 1937 to organise the production of war supplies. In the early 1940s after the outbreak of World War II, the War Supplies Board was replaced by another body called the Director General of War Supplies. This organisation was tasked with defence acquisitions and manufacture of goods destined for the war efforts. Purchases and manufacturing were centred on the existing local iron and steel industry; the explosives operations established in 1936; engineering units of mine workshops; and state railway workshops. At the time, the mandate of the Director General of War Supplies was extended to take over civilian supplies and therefore it was renamed the Director General of Supplies (DGS) Rogerson (1990). This is evidence of some of the earliest collaboration efforts and the development of the defence industry. Figure 11 in Appendix 1 shows how the entity now known as ARMSCOR came to be, which according to Rogerson (1990) has evolved from DGS above.

ARMSCOR's mission as stated on its website is "to meet the acquisition, maintenance and disposal needs of the South African Department of Defence and other clients in terms of defence materiel, related products and services. ARMSCOR maintains strategic capabilities and technologies and promotes the local defence-related industry" ("About ARMSCOR," n.d.). A clear indication of ARMSCOR's mandate which it is still undertaking is entering into collaboration agreements with the local defence industry.

After the Second World War, defence spending decreased but was revived in the 1960s. 1960 was a significant time in South African history, with a great deal spent on defence, because of the pass law protestors' massacre in Sharpeville; coupled with the banning of the liberation movements, the ANC and the PAC; and other factors (Rogerson, 1990). The PAC and ANC declared an armed struggle against the state and were also the catalyst of intensive defence spending by the state (Rogerson, 1990). These events, including the Sharpeville massacre, prompted the UN Security Council to adopt Resolution 181 in August 1963 asking member states to voluntarily cease the sale and shipment of arms, ammunition and military vehicles to South Africa (Dugard, 1991). The results of the arms struggle declaration and the UN resolution led to a shift from importation of arms in the 1950s to the local production of arms (Rogerson, 1990). This was a road towards the industrialisation of the South African military, with a high increase in defence spending which eventually led to self sufficiency of the industry (Dunne & Haines, 2002; Rogerson, 1990).

ARMSCOR's mandate was to collaborate with defence contractors in developing a notable defence industry. By the 1980s South Africa had capacity for indigenous manufacture of military aircrafts, missile systems, armoured and mine protected vehicles, naval warships, infantry weapons and military telecommunications and electronics (Bitzinger, 2003).

In 1992 ARMSCOR was split into two entities - Denel, a state owned defence contractor that inherited all the manufacturing and research facilities of ARMSCOR, and ARMSCOR, which concentrated on defence acquisitions and development of the industry (Dunne & Haines, 2002). Denel's market share was 48 percent of the defence market in 1992 and the other large private defence contractors (Reunert, Grintek and Altech) started to consolidate their positions through acquisitions of small and medium sized private defence firms (Dunne & Haines, 2002). Some of the organisations in this sector that started as small entities have since been acquired by major global defence companies as an entry point to the South African defence industry (Bitzinger, 2003; Dunne & Haines, 2002). The role of private defence contractors has evolved from not only supplying the South African industry but to now playing in the export market (Bitzinger, 2003; Dunne & Haines, 2002). This was because the transition to democracy and the ending of apartheid led to a demilitarisation of South Africa, resulting in dramatic defence budget cuts from the South African government (Bitzinger, 2003; Dunne & Haines, 2002). Furthermore, the South African defence contractors also increased their supply networks to leverage on the capabilities that were once closed to them as they started to improve collaboration as a strategy. This shows that strategies of defence contractors had to evolve, meaning they needed to understand the impact of their operational decisions, capabilities and policies to support their strategy.

According to Dunne and Haines (2002), when the new government realised that it could not continue with aging military equipment because of the earlier defence cuts, it invited foreign based companies to tender for the supply of military equipment. The contracting conditions included offset obligations to South African industries. Offset obligations are conditions that foreign based suppliers must meet when awarded contracts by developing the local industry through technology transfers and economic development. In South Africa it meant that the local defence contractors entered into collaborative agreements with foreign based companies which included CPD activities (Dunne & Haines, 2002). A 2008 headline from Engineering News online read that "BAE Systems, Saab claim to have met 60% of offset obligation" (Campbell, 2008a), which meant that after the offset obligations are met the local defence contractors will be faced with making other strategic and operational decisions. This also illustrates the complexity of the industry, where in some cases collaboration can be enforced through offset obligations.

## 2.3 Mine protected and armoured vehicles

Stiff (1986) stated that in 1972, as a result of increased incidences of landmine casualties on South African policemen in the Caprivi Strip (Namibia region), an urgent need arose for the Defence Research Unit of South Africa (DRU) to review the design of mine protected vehicles. He added that this led to CPD of vehicles that would protect passengers from injury or death by landmine blasts. The collaboration parties included the DRU; the South African Police (SAP) now known as SAPS; defence companies such as Messrs Sandock-Astral and Rhodesians (now known as Zimbabweans); and observers in the design, prototyping, manufacture and testing of vehicles (Stiff, 1986). South Africa's history of local design and manufacture of armoured cars dates as far back as the World Wars where an earlier prototype was delivered on September 18, 1939 (Campbell, 2008b). South Africa has over the years developed so many mine protected and armoured vehicles through collaboration efforts, that today it is recognised as a one of the leading countries in the world on mine protected, mine detection and armoured mine protected vehicles (Campbell, 2008b).

The motivation for CPD in 1972 was loss of lives of military personnel and civilians that forced the then government to act due to internal public opinion. Today the reasons behind collaboration for defence contractors may include the survival of the entity, especially where offset obligations are prevalent or where participation of SMEs is a prerequisite for the awarding of tenders. Eshuis and Ludwig (2006) stated that business trends include fast time to market for products that require that networked collaborations must be dynamic, flexible and adaptable. They have also found that frequently there may be heterogeneous partners who need to be integrated, and problems that are raised during these processes include how to manage trust and how to support electronic contracting (Eshuis & Ludwig, 2006). With enforced collaboration like offset obligations or any other form of collaboration, these issues can affect EC of products or ECM processes and thus the lead time, quality and cost of the products to the customer.

Another challenge that defence contractors in South Africa face is that the historic defence cuts have also led to some companies having to convert portions of their business for commercial customers who have different requirements (Dunne & Haines, 2002; Rogerson, 1996). These changing landscapes have their own dynamics because commercial partners normally have shorter lead times than the government acquisitions agencies. This marks the importance of having well aligned and integrated business processes that are flexible and reliable to cater for different types of customers.

## 2.4 Strategy overview

Having understood the landscape and the context of the defence industry and how the industry needs to progress, an explanation of strategy is fitting for companies to understand how they can be able to adopt CPD as a strategy and use ECM as its enabler. Andrews (1980, p.13) explained corporate strategy as a “pattern of decisions in a company that determines and reveals its objectives, purposes, or goals, produces the principal policies and plans for achieving those goals, and defines the range of business the company is to pursue, the kind of economic and human organization it is or intends to be, and the nature of the economic and non-economic contribution”. CPD is regarded as a strategic decision that is part of a pattern of decisions that are aimed to be effective over long periods of time. Firms that will adopt CPD as a strategy need to understand the dynamics, challenges and benefits that can be derived in the execution of CPD as a strategy. When ECM is introduced, it needs to be one of many operating mechanisms in a company that interact and are important for the execution of CPD as a strategy. This speaks to issues of internal and external alignment of business processes like ECM and how information will flow to ensure the company will be able to respond to the evolving customer needs and changing landscape.

## 2.5 Enabling collaboration

The defence industry is currently undergoing various significant changes where the governments are spending less on defence, there is increased dependence on global supply chains, costs are rising, and fuel costs are fluctuating. The industry also has to contend with various regulatory frameworks locally and globally (Farrant & Mommeja, 2009). Danese (2013) argued that increases in global competition are forcing companies to rethink their strategies where supplier and production networks have undergone significant changes in order to serve customers better. The key to growth, therefore, in a rapidly changing world is for businesses to adapt and increase emphasis on product innovation, collaboration and operational excellence (Farrant & Mommeja, 2009).

Shafiei, Sundaram and Piramuthu (2012) stated that in order to remain competitive, firms need to share information with their supplier partners and to gather information from their customers and customer facing partners. According to Chen et al. (2008), sharing of information is not exchanging conventional data; rather it refers to integration of distributed design work by sharing knowledge. The implementation of CPD consists, amongst others, of remote process formation and control, dynamic integration of design activities and the management and sharing of heterogeneous resources, which if not managed well will defy the reasons why companies collaborate in the first place. The human elements include team alignment through shared values and effective partnership through creation of mutual trust and well defined expectations (Chen et al., 2008). Danese (2013) argued that supplier integration is linked to an improvement in company performance with specific reference to fast supply network structures. This illustrates the need for a company to overcome constraints that lead to ineffective collaboration.

Four challenges for effective collaboration have been identified as:

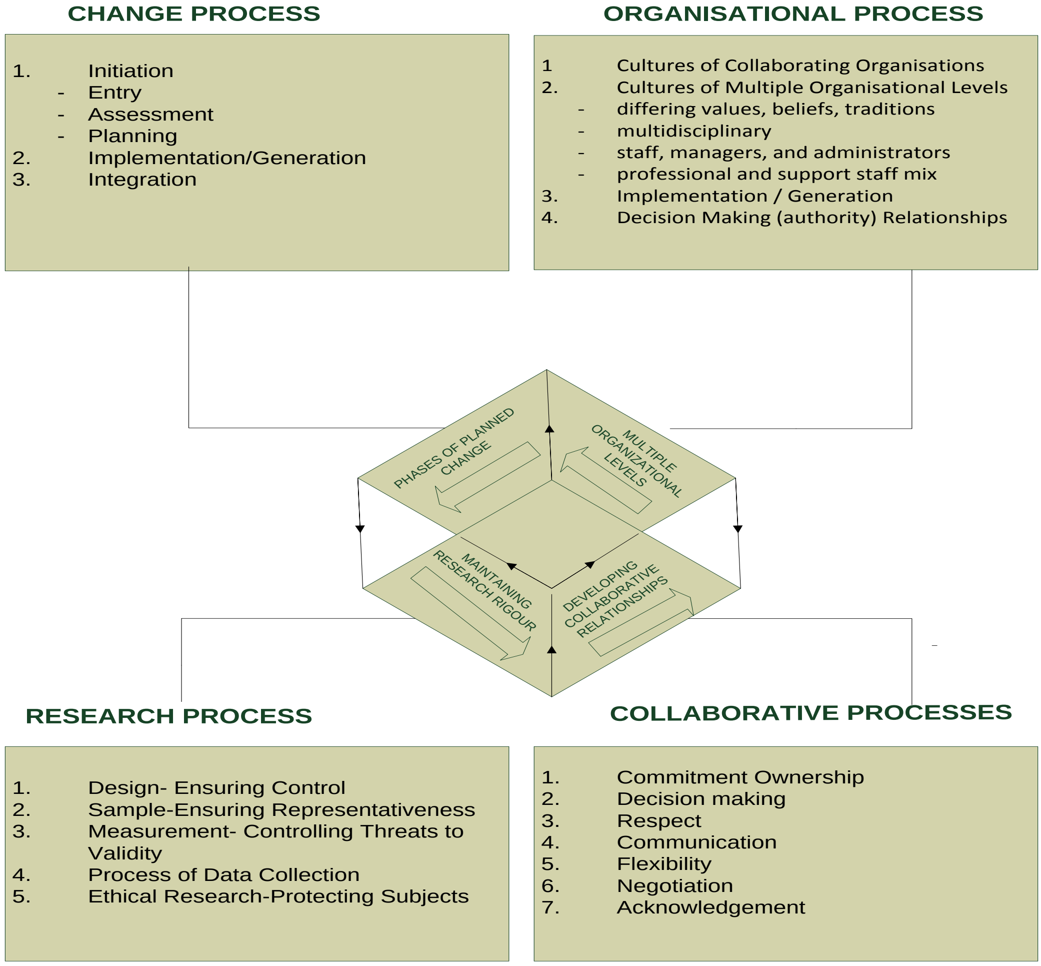
- “Identification of the sources of competency, skills and business value.
- Motivation of the partners who need to collaborate.
- Need for a process framework that imposes only the applicable and minimum levels for commonality between the participants’ information and processes.
- Organisational alignment to enable partners to interact effectively and flexibly while minimizing the impact of change within their organizations” (Farrant & Mommeja, 2009, p.4).

These are challenges that companies in collaboration face which are complex and become even complicated when ECM processes are included. A substantial portion of this research sought to look at innovative ways to establish a model that may address these challenges in an ECM context for the efficient development of high quality products.

Farrant and Mommeja (2009) found that in a CPD environment the adaptable business becomes an innovator by understanding the four challenges mentioned above, where the outcome is the exploitation of a shared vision between member partners to gain a competitive advantage. Bititci, Martinez, Albores and Parung (2004, p.251) stated in their study that “collaboration should result in the creation of new and unique value propositions based on a unified approach to value creation”. In this case, therefore, the innovator will need to understand the role and competencies of members in the CPD environment or ecosystem for creating value. Secondly, the focus will be on attracting complementary organisations and to keep improving. Lastly, the use of data extracted from the collaborative ecosystems needs to be a source of knowledge that will influence decision making and control (Farrant & Mommeja, 2009). These principles explained above were evaluated in the South African land systems defence context, where challenges include how to integrate with suppliers that are critical to your company performance but may be immature in their processes.

### 2.5.1 A model for collaborative research – addressing complexities and challenges

**Figure 1: A model of collaborative research**




LeGris et al. (2000) developed the model shown in Figure 1 for collaborative research after realising the dynamic interaction of multiple forces that exist in a collaborative environment. In this research, the multiple actors include suppliers' companies and subcontractors, buyer companies, partners and customers, and the end users of products. The processes involve supplier integration, ECM processes, collaborative processes and change management processes, and thus the model that was developed took into account these complexities.

## 2.6 Engineering Change Management

According to Reddi and Moon (2011), the aim of EC is to correct faults, exploit new market opportunities, reduce overall costs and improve overall product performance. How then have companies in the land systems sector fared in the above? Secondly, Wasmer et al. (2011) have shown that in the automotive industry, the need for ECM has been established to address the problems of multiple systems and formats of ECMs, multiple definitions, terminology and processes, multiple skills sets needed to support multi process / system, missing information, conflicting changes, insufficient change tracking, deficient communication of change to all stakeholders, wait time / responsiveness, and unauthorised changes processed resulting in costly time and process delays. They pointed out that with the implementation of an effective and efficient ECM process, there are potential benefits of reduced lead time to market for products, increased predictability of products therefore higher quality standards, and reduced legal and reputational risks for the company (Wasmer et al., 2011). Reddi and Moon (2011) furthermore stated that for companies to be competitive - especially those engaged in new product development - they need to have systems in place that accommodate product or process changes.

The uncertainty in the defence sector and the evolving needs of customers make it important for companies to quickly accommodate customer or market design changes effectively and efficiently. Companies that are able to accommodate these changes may have an edge in getting contracts because of their flexibility. Their processes and decision assistance tools that they utilise need to ensure that time is reduced in processing EC as agreed by all stakeholders. How the information is relayed and processed in the supply chain managing EC is critical in improving the quality of the products. These systems must be reliable with respect to accuracy and interpretation of information pertaining to EC.

### 2.6.1 Change propagation

Giffin et al. (2009) defined change propagation as a process where a change in one part may affect additional changes to some other parts on the systems or configuration. A study by Brown (2006) of Aberdeen Group found that engineering changes are frequent and expensive, leading to scrap, wastage in inventory, additional cost of rework, as well as disruptions to the supply chain. He found that many companies are therefore likely to focus on reducing changes and pointed out that design is an iterative process that leads to innovation. This innovation can be achieved through virtual iterations to validate designs. The impact of physical changes can be reduced if changes are adequately addressed by virtual simulations. This makes ECM a process that undertakes to effectively deal with changes intelligently by understanding the design relationships and their impact to change in systems (Brown, 2006).

It then becomes important to evaluate change propagation within CPD and effectively manage it, especially where there is an innovative company that views change as a cost benefit versus one that is focusing on reducing change orders (Brown, 2006). This is further evidence of the need for creating shared values when embarking on a CPD and the complexities of organisational alignment that exist. Hung et al. (2011) suggested that organisational issues may be overcome by choosing those suppliers who are open to having their products and processes scrutinised. They have shown that this can create a strong advantage for companies in a CPD environment (Hung et al., 2011).

### 2.6.2 ECM information exchange model

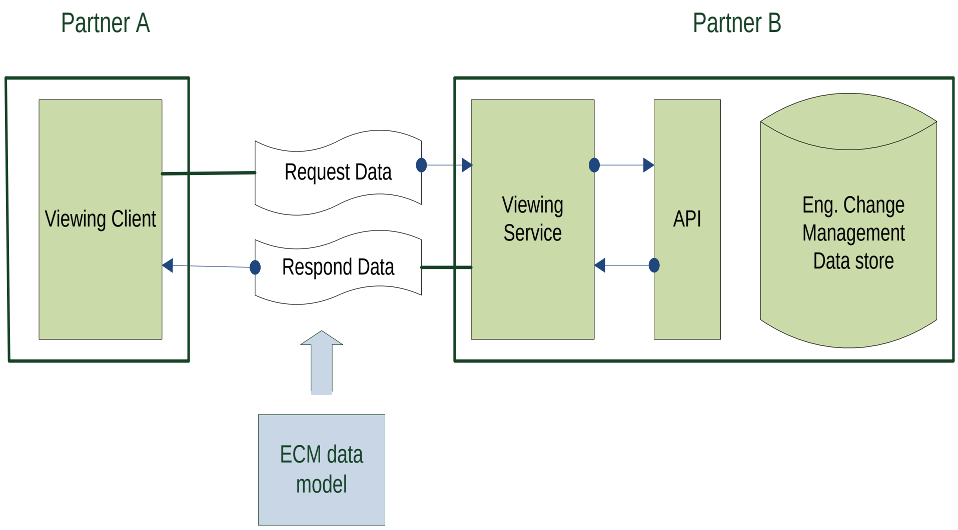
Danese (2013) has found that firms are outsourcing more activities where they need to coordinate global networks internationally and locally. Supply chain integration, which is sometimes called supplier collaboration, has a subset that includes new product or process development. In this instance it is created to seamlessly coordinate information and material flows that are considered good performance levels for a company (Danese, 2013). Danese (2013) further stated that supplier integration can generate knowledge that is crucial for achieving an advantage over competitors.

The Strategic Automotive Standards Industry Group (SASIG), a global organisation in the automotive industry that acts as a forum to develop global standards, guidelines and recommendations, and promotes the implementation of automotive engineering standards, has identified three ways in which information can be exchanged by two organisations in a collaborative environment (SASIG, 2009). They are: data orientated integration model, process orientated integration model and the third model is a hybrid of data and process orientated models.

#### 2.6.2.1 Data orientated integration model

Figure 2 is typically a process where the engineering changes can have minimal effect. Partner A's processes are not that much affected by the EC that partner B has implemented. Data is exchanged where partner A would request information on changes made by partner B, who would respond by providing the information. This type of data exchange model is called data orientated integration (SASIG, 2009).

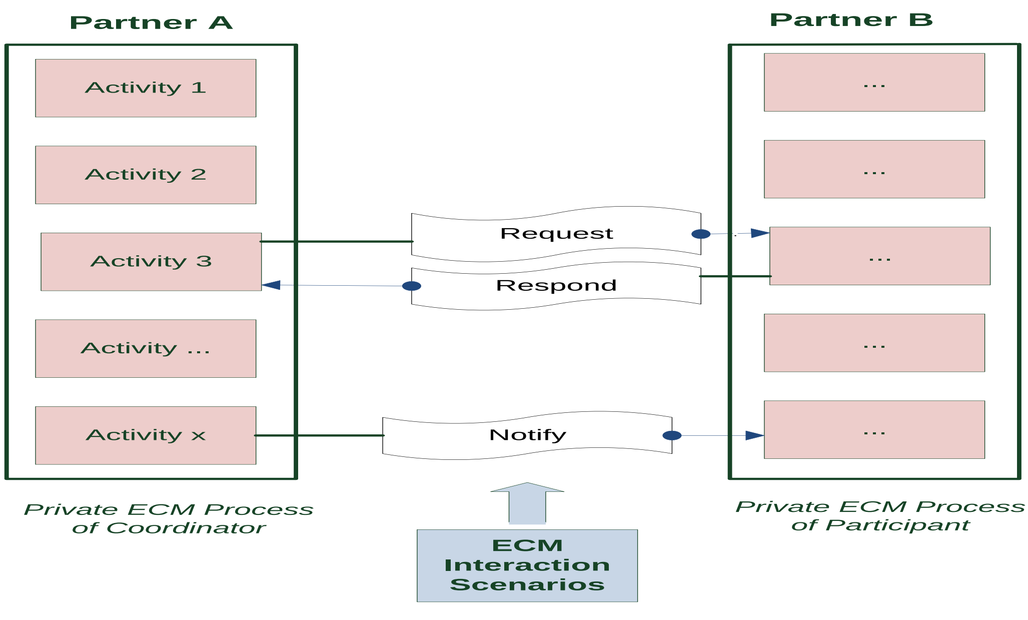
**Figure 2: A schematic representation of a data orientated integration model (SASIG, 2009)**



#### 2.6.2.2 Process orientated integration model

Figure 3 below is a representation of a model where there are dependencies between the engineering processes of partners A and B. For example, the EC of a product manufactured by partner B will affect the performance of a product manufactured by partner A. This can also happen vice versa, where for example partner A can request partner B to customise a product produced by B. The example illustrates the concept of CPD taking place with EC undertaken by the two partners. The middle of the diagram represents the bilateral communication that must happen between the two partners and it also means that the private ECM processes of partner A interacts with the private ECM process of partner B. The scope and the quantity of exchange between the partners and the required interventions will depend on the tasks and process roles distributed between them (SASIG, 2009).

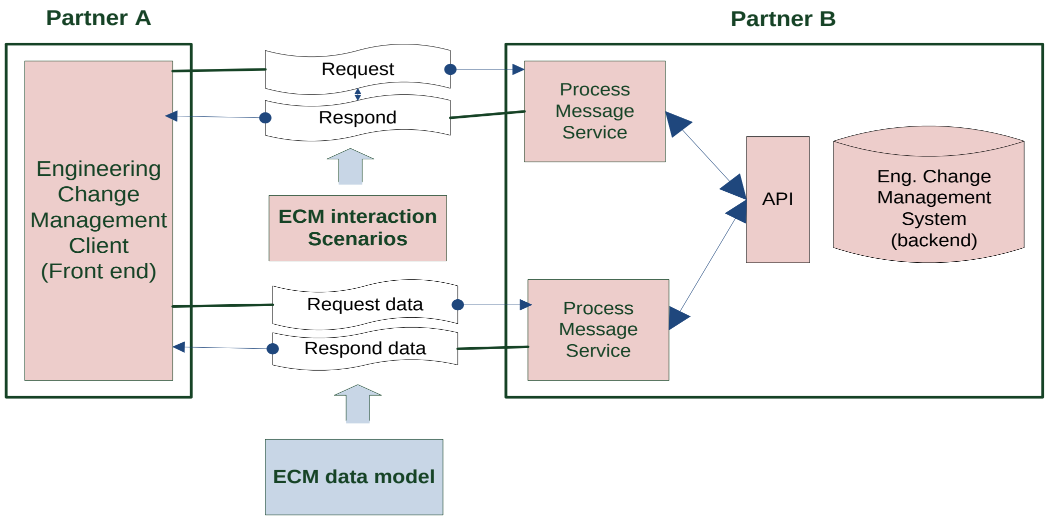
**Figure 3: A schematic representation of a process orientated integration model(SASIG, 2009)**




#### 2.6.2.3 Hybrid, data and process orientated integration model

Eshuis and Ludwig (2006) have shown that collaboration requires "the business processes of the partner companies to be aligned and integrated with each other, both on a process and data level in a dynamic, ad hoc fashion". This was also supported by Danese (2013), whose study indicated that supplier integration positively affects the performance of the buying firms in efficiency, schedule attainment and flexibility. Figure 4 illustrates a combination or hybrid data and process integration model. EC that have no impact on one partner's ECM process are treated as explained above on a data orientated integration model to reduce time. Those EC with impact on the processes are treated using the model of process orientated integration model and given priority (SASIG, 2009).

**Figure 4: A schematic representation of the hybrid data and process orientated integration model (SASIG, 2009)**




This research was conducted by evaluating the applicability of these information flow models in managing EC. The reasons for adopting one model over another were examined to see how they facilitated ECM as an enabler in CPD.

### 2.6.3 Evaluating the ECM processes

It has been established that EC are unavoidable and therefore require a knowledge management process within the ECM framework that considers capabilities of capturing EC, sharing them and archiving them into a knowledge repository (Chen et al., 2008; Wasmer et al., 2011). Wasmer et al. (2011) indicated that a 2005 automotive industry study on EC revealed that there were around 350,000 EC in the supply chain of

Ford, GM and Daimler Chrysler's per year (Brown, 2006; Wasmer et al., 2011). Looking at this staggering number, it shows that EC can be costly to a company, but at the same time can guarantee a high end product if viewed by a company as a cost benefit (Brown, 2006; Wasmer et al., 2011). The defence sector can learn from the automotive sector with regards to ECM, but these are also different industries especially with regards to the volumes produced. The automotive industry may have the benefit of extensive information feedback on the problems experienced by the end-users or customers for generating EC. The defence sector may not have the same luxury for feedback from its end-users or customers. If products fail in service during warfare it may already be too late for soldiers. This highlights the need for an effective ECM process for products delivered by defence contractors. It is therefore important for a company to evaluate its ECM processes, especially in a collaborative environment not only because of cost, but for designing products that meet customer needs. Strategically, a company should benefit from effective management of EC.

Reddi and Moon (2011) viewed engineering changes as opportunities to stay competitive and thus companies must strive to implement them at the lowest cost possible. The evaluation of these ECM processes sought to establish how mature or sophisticated the ECM processes were for the companies that were studied and their impact on being competitive. Another factor that was considered was the ECM processes of their suppliers that they are collaborating with, to see if they were a hindrance or not in effecting design changes to meet customer demand with respect to cost, schedule and quality.

### 2.6.4 Leveraging ECM

A CPD environment, as explained previously, makes use of workflows and collection of software applications, that according to Habhouba, Cherkaoui and Desrochers (2011), must be integrated to manage EC. Ouertani (2008) has indicated that designers do not only look at functional requirements when designing products, but they need to consider geometrical, behavioural and other requirements. These intricacies may lead to conflicting ideas or solutions between designers engaged in CPD (Ouertani, 2008). It may make the design process complicated and lead to longer lead times, which is the reason Habhouba et al. (2011) designed an architecture that has a decision making tool for conflict resolution. They have in their research found that teams in a CPD environment need to automate their communication and negotiation with regards to EC. The benefit, as they describe it, is to find optimal solutions that save time and money through the use of intelligent tools for collaboration in ensuring effective ECM. In support of Habhouba et al., Shafiei et al. (2012) stated that in today's business environment, decision makers do not have time to locate data or information. Instead, decision makers demand tools that are open and flexible, that can be integrated with processes of their suppliers or customers. In response, Habhouba et al. (2011) stated that their architecture, EchoMag, automates the decision making of designers in the ECM processes. Secondly, this architecture helps to improve communication of members in a CPD team and finally, anyone in the CPD team can extract information concerning EC requests. The improvement in decision making and conflict resolutions is thus helpful in a CPD environment.

Habhouba et al. (2011) designed EchoMag as a decision making tool to leverage ECM processes, and their pictorial architectural overview is shown in Figure 12, Appendix 1. The basis of EchoMag as a system that can be used to leverage ECM is on three core modules. The first module is the Engineering Change Management and Archiving module that manages and archives change management requests made by designers. The second module is the Multiagents System that is used to check whether proposed changes can be accepted, refined or discarded. The third module in EchoMag is called the Constraints Management module that allows definition of design and manufacturing constraints on products and it interfaces with corresponding CAD models that companies use (Habhouba et al., 2011). Ouertani (2008) stated that collaborative design is constraint orientated and there are many interdependent parts that impact or may have consequences on other parts. This clearly illustrates the need to leverage ECM processes in a systematic processes as described by Habhouba et al.'s (2011) EchoMag tool. The ECM processes of the companies that were researched were evaluated against the EchoMag tool because of its potential in leveraging ECM processes.

## 2.7 Conclusion

The literature clearly indicates the need for processes to be integrated, which would require the companies to open their products and processes to scrutiny. This requires a higher level of trust so that information can flow between the two companies that are designing products collaboratively. Companies do, however, choose the way they will interact with their suppliers and customers by making use of a different communication platform. They will require decision assistance tools such as EchoMag that have good features for companies to use in communications and resolving dependencies which are critical for designers. In their absence, how would a company, especially those with immature processes, fare? This is the reality in South Africa and thus the model that was designed took into account the applicability of the given environment.

# Chapter 3: Research Problems

## 3.1 Research Aim

The aim of this research was to determine the extent to which the management of EC affects design performance in a collaborative environment. It was also more specifically to gain a deeper understanding of how information flow exchange models enable or constrain design performance of collaborative partners. It is envisaged that the study will contribute toward a better understanding of current and best practices in collaborative design and identify gaps for improvement within the South African context.

## 3.2 Research Question 1

What are the key constraints to design performance in the context of the South African land systems sector of defence?

## 3.3 Research Question 2

To what extent is the speed of EC affected by the nature of the information exchange models adopted?

These questions sought to determine the extent to which South African companies engaged in CPD in the land systems sector are utilising ECM processes as a source of competency. Secondly, they seek to examine the mechanism utilised by collaborative partners to interact, align processes, and more importantly, to integrate effectively. The key themes that were examined were on collaboration models and how information is shared. In addition, constraints were identified as well as best practices for innovation in the management of EC.

# Chapter 4: Research Methodology

## 4.1 Methodology and Rationale for Qualitative Study

The landscape of the land systems defence sector in South Africa has changed, where companies that once enjoyed the protection of the states with regards to securing tenders have to compete in a global environment. To understand how business processes have evolved and the context of decision making in this sector, an exploratory research was conducted. According to Saunders and Lewis (2012), an exploratory study seeks to assess a topic in a new light and to gain a fuller understanding of the situation. In support of this, Hanson, Balmer and Giardino (2011) stated that qualitative research is able to explore the unexpected and it employs a largely inductive approach to analysing data. Secondly, Granot, Brashear and Motta (2012) have shown that phenomenological research, which is a subset of a qualitative study, is able to provide a fuller appreciation of complexities, intricacies as well as difficulties in change, which is relevant in this study where the extent and impact of EC are variables. Thirdly, Reddi (2011) in his doctoral dissertation, pointed out that research on ECM in a collaborative environment is very limited, which is further motivation for a qualitative study. Fourthly, to critically evaluate the research problems, a qualitative study is important because of its flexibility in allowing for incorporation of important, but unexpected, events and findings (Hanson et al., 2011). Furthermore, in defence of why a qualitative study was chosen, Goulding (2005) found that phenomenological research may be beneficial in theory building, which is based on lived experiences of strategic decision making. In conclusion, the questions asked in an exploratory study are ‘how’ and ‘why’, which are best suited when one wants to gain new insights or to explore a phenomenon in detail, which may sometimes not be possible with a survey research design (Crabb & Chur-Hansen, 2009; Saunders & Lewis, 2012).

## 4.2 Population of Relevance

The population of relevance was the companies that conduct CPD in the defence sector; particularly the armoured, mine protected and mine detection vehicles manufacturers' sub-sector. Three companies in the land systems sector were selected from a total of seven within this sector. These seven companies are all members of the South African Aerospace, Maritime and Defence Industries Association, commonly known as AMD, which is the main industry body representing the defence sector in South Africa. Although three companies were chosen, interviews were conducted in two of the three companies, but information was gathered from company websites and articles for the third company. The selection of the companies was based on their market size and market leadership, history of collaboration, export performance in terms of products, innovative products they developed, access, contacts within the industry and the researcher knowledge of the industry. This selection criterion was informed by the researcher's judgement to match the companies in line with the information that is required to conduct the research. Where information was limited from the interviews, data were also collected from company websites and news articles to corroborate the interviews.

## 4.3 Unit of Analysis

The unit of analysis for this research report was the information and experiences of the design engineers and programme managers of companies in the armoured and mine protected sub-sector of the defence industry. The engineering managers / product engineers that were interviewed had at least an Honours degree in engineering, with the majority also having a Masters degree in either engineering or engineering management. This speaks to the credibility of the information and is also supported by their experience, which on average was over 10 years per manager.

## 4.4 Sampling Technique

A purposive sampling technique was conducted, which as stated by Saunders and Lewis (2012) is a non-probability sampling technique using a reseacher's judgement. The research was mainly conducted at OMC, the largest South African division of BAE Systems, which has a large range of products for the South African and export markets with different dynamics and needs. Its sister companies, Gear Ratio and Dynamics, were also analysed as autonomous units and as suppliers to the larger division, OMC. Design engineers were chosen based on a critical case variety of purposive sampling, meaning that those selected would be essential to the operation of the research process (Saunders & Lewis (2012). The majority of the respondents were from BAE Systems Land Systems South Africa.

## 4.5 Sample Size

Crabb and Chur-Hansen (2009) stated that qualitative research is based on a relatively small sample. The goal was not to generalise findings, but participants were targeted specifically for their knowledge and experience relevant to the research questions (Crabb & Chur-Hansen, 2009). The number of participants interviewed was thirteen before saturation point was reached.

## 4.6 Data Collection

In their study, Hanson et al. (2011) found that interviews are used for the purpose of understanding people's thoughts and experiences, therefore underlying issues regarding design performance due to ECM in a collaborative environment were emphasised. This study made use of open-ended and flexible or semi-structured interviewing techniques to cover all the relevant topics in line with the research questions and themes (Hanson et al., 2011). Semi-structured interviews were conducted with the technical director of BAE Systems Land Systems South Africa and the engineering managers of the following programmes - driveline systems at Gear Ratio, engineering managers of several types of vehicle programmes at OMC and engineering managers from

Dynamics. Interviews were also conducted with two other programme managers - one from an engine, Original Equipment Manufacturer (OEM) supplying to OMC, and another from another defence contractor within the land systems sector.

An interview guide, with main and probing questions, was utilised to ensure comprehensiveness and focus for data collection (Hanson et al., 2011). Flexibility was allowed in the interviews to allow for unexpected results that could have some importance in understanding the research study.

## 4.7 Data Analysis

According to Hanson et al. (2011), the use of audio-visual devices in qualitative research is to capture detailed descriptions of complex behaviours, processes, relationships, settings and systems; therefore all the interviews that were conducted were recorded.

Data were analysed using the guideline of Coliazzi's (1978) method below, as illustrated in Goulding's (2005) article:

Step 1: The participants' narratives were read and listened to, to fully comprehend and understand their ideas.

Step 2: Significant statements relating to the research problems and phenomena were extracted.

Step 3: Formulation of meanings to significant statements was carried out.

Step 4: Steps 1-3 were reiterated where recurrent meaningful themes were discovered and clustered.

Step 5: An integration of the resulting themes to form patterns or phenomenon was conducted.

Step 6: A structure was formulated to reduce the themes and start the development of the model.

Step 7: The interpretation of the model was evaluated against the literature reviewed.

The data analysis was conducted on the ATLAS.ti qualitative analysis and research software tool.

## 4.8 Research Limitations

The experiences and views of the end users of products were not included in the study. Firstly, Armscor and SANDF were not included in this study because of their approach to limiting the number of EC and keeping the status quo. Secondly, the researcher would not have access to the end users outside of South Africa nor to the defence contractors because they would normally sell their products through local partnerships or through government acquisition companies. The absence of information from this constituency limited the analysis by potentially introducing bias in terms of the model not being fully representative of all stakeholders.

# Chapter 5: Results

## 5.1 Introduction

The interviews were structured around the themes of collaboration and how information is shared by identifying constraints and best practices for ECM innovations. This was informed by the theory that EC are important because of their influence on product lead time, cost and productivity and how they enable an organisation to respond to dynamic market conditions. However, EC can be complex and their complexity also increases dramatically when several companies are involved collaboratively. The interviews were conducted based on the literature reviewed in chapter 2. Data gathered from the thirteen interviews conducted are summarised in the tables and figures below to illustrate the emerging themes. The data were coded in Atlas.ti by theme and then extracted into Microsoft Word and Excel. Information in each table in this chapter was rank ordered according to a frequency analysis if there was more than one category within a table.

## 5.2 Interviews

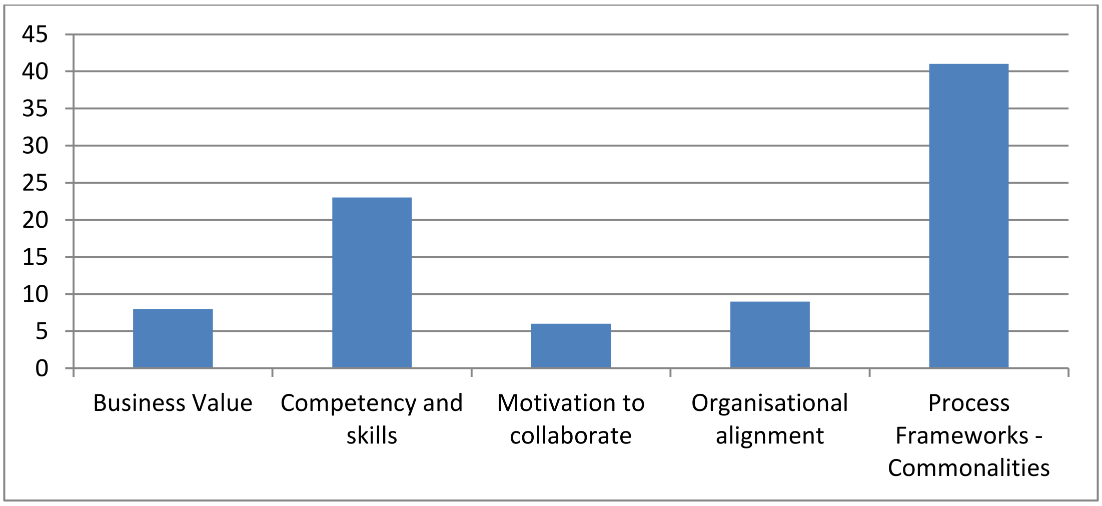
The interviews were conducted with the following people below:

- The technical director for BAE Systems LSSA;
- Six engineering managers from OMC, the vehicle manufacturing division of BAE Systems LSSA;
- Two engineering managers from BAE Systems LSSA - Dynamics division that manufactures turrets and fire directing systems;
- Two engineering managers from BAE Systems LSSA - Gear Ratio, the driveline and power-train division;
- A technical representative for the South African division of a multinational OEM that supplies engines to OMC; and
- A product manager from another land systems defence contractor to also share best practices and innovations.

## 5.3 Research Question 1 - What are the key constraints to design performance in the context of the South African land systems sector of defence?

In chapter 2, Farrant and Mommeja (2009) identified several challenges that may render collaborative efforts ineffective and by understanding them, then decision making at strategic, operational and tactical level becomes easier. These challenges informed how research question one was evaluated and the results are shown below in Figure 5 according to the themes that were identified from Table 1 to Table 10. Coliazzi's method as described in chapter four was used as a guideline in analysing the data about the challenges or constraints in the land systems sector that affect design performance. The themes were then discovered and clustered after codification. These constraints were collectively clustered around the five common themes discovered which are shown in Figure 5 as skills and competencies between different organisations in a CPD, motivation to collaborate, common processes for information flow and organisational alignment for effectiveness in collaboration.

**Figure 5: Key constraints to CPD performance**




In summary, the result show business processes as posing significant challenges towards design performance as compared to other constraints. The details of these constraints are discussed from Table 1 to Table 10.

### 5.3.1 Challenges of operating in a low volume industry

Table 1 sets the context of operating in the defence land systems sector. It is characterised by low volumes as opposed to the high volumes in the automotive sector. The products are complex and are generally customised.

**Table 1: Constraints of operating in a low volume environment**

| Respondents | Theme, remarks or challenges |
|---|---|
| P2; P4; P5; P6; P7; P11 | (Motivation to collaborate) Challenges in ordering low quantities from OEM are in pricing, capacity of suppliers for ongoing support in spare parts, getting development support for customised products and getting the required quantities within the lead time required. |

### 5.3.2 Attracting mature suppliers

Interviewees also responded on the challenges in attracting mature suppliers as shown in Table 2 and this also sets the context in terms of constraints when operating in the land systems sector.

**Table 2: Inability to attract mature suppliers**

| Respondents | Theme, remarks or challenges |
|---|---|
| P2; P4; P5; P6; P7; P10; P11; P13; P14 | (Competency and skills) The suppliers may not have the maturity level or capability that companies in the land systems require. This is because of the low volumes thus making it necessary to develop suppliers. These suppliers may sometimes not cope with the pace of EC or any other industry related changes. |

### 5.3.3 Language barriers

Table 3 shows that two interviewees highlighted language barriers as a challenge to design performance.

**Table 3: Miscommunication of product definitions due to language differences**

| Respondents | Theme, remarks or challenges |
|---|---|
| P2; P14 | (Competency and skills) There are instances where language can be a barrier to communication and may lead to misinterpretation of product definitions, thus leading to EC. Where language barriers, may pose a challenge, it is important for the product definitions to be thoroughly clarified at conceptual phases before detailed designs are finalised and prototypes are built. |

### 5.3.4 Challenges in customer and supplier management within CPD

Table 4 shows the challenges companies face in managing relationships within a CPD environment. It is important for a company to identify these challenges to ensure effective collaboration which has an impact on design performance.

**Table 4: Challenges for effective collaboration in managing collaborative partners**

| Respondents | Theme, remarks or challenges |
|---|---|
| P4; P10; P11; P14 | (Process Frameworks – Commonalities) Companies that don't have processes and systems that can help to track their products performance in the field. |
| P6; P7; P8; P14 | (Organisational alignment) Challenges in managing customer relationship where programmes are impacted by EC that emanated internally and externally from the customers and still meet expected deadline. |

| | |
|---|---|
| P7; P11; P13 | (Competency and skills) Challenges in changing the way companies conduct business by making suppliers system responsible according to their capability and availability. |
| P7; P13 | (Competency and skills) Collaborative arrangements involving partners that are not well versed in one's companies' activities or end user requirements. |
| P 4; P5 | (Business Value) Challenges where the suppliers or customers are powerful enough that they can destabilise a company's delivery requirements. |
| P7 | (Business Value) Customers complain that they are not involved in the design process versus a company practice that wants customer interactions to be limited. |

### 5.3.5 Storing and information retrieval processes

Table 5 is about what processes and systems need to be in place to ensure information about that EC or any other process are effectively stored and can be retrieved without wasting time and reducing productivity.

**Table 5: Challenges in managing storing and retrieval information and communicating**

| Respondents | Theme, remarks or challenges |
|---|---|
| P2; P4; P5; P7; P8; P13; P14 | (Process Frameworks – Commonalities) If the information for Engineering Change Proposal (ECP) or communication within the supply chain is not stored in a systematic, methodical way, it may lead to challenges with its tracking, retrieval and documentation. This also means that mistakes or errors may be repeated or perhaps best design processes may not be followed. |

| | |
|---|---|
| P2; P3; P4; P9; P12; P14 | (Process Frameworks – Commonalities) Challenges when there are no guidelines or processes that force or enable information to be stored in specific locations in a systematic way to help with information retrieval and for business continuity. |

### 5.3.6 Challenges in knowledge transfer

Companies are affected by knowledge transfer as shown in Table 6.

**Table 6: Challenges in ensuring knowledge is transferred**

| Respondents | Theme, remarks or challenges |
|---|---|
| P2; P4; P10; P13; | (Organisational alignment) Collaboration challenges include how information is going to be transferred to partner organisations that are in different geographies to ensure consistency and uniformity in design and production processes as well as people as resources who either resign or are transferred programmes. |

### 5.3.7 Challenges in EC systems

Technology is driving processes and Table 7 shows the challenges that companies may face if their EC processes are manually driven.

**Table 7: Constraints due to EC processes and systems**

| Respondents | Theme, remarks or challenges |
|---|---|
| P2; P3; P7; | (Process Frameworks – Commonalities) Manually driven EC processes, especially in large companies, may not be ideal processes for storing and retrieval of data in a time efficient way. |
| P2; P9; P13 | (Process Frameworks – Commonalities) Mistakes can happen with the manual capturing of data due to human error and that can leave design dependencies open to error - especially where ECP need to be conducted speedily. |

### 5.3.8 Challenges in EC resources

Companies may have limited resources to conduct EC requirements as illustrated by the experiences of interviewees in Table 8, thus impacting on the design performance.

**Table 8: Constraints due to limited resources**

| Respondents | Theme, remarks or challenges |
|---|---|
| P3; P4; P5; P6; P7; P9; P11; P13 | (Process Frameworks – Commonalities) Customer requested EC or any other EC must be addressed in a structured format consistently and according to the company resources, because one can tend to underestimate what impact the change of a variable can have on the schedule, cost and delivery of a project. |
| P4; P5; P7; P9; P11 | (Business Value) Not all customers want EC, however legitimate to their products, because of the resources that they have in a particular financial year. This will affect their level of interaction and meeting performance objectives with regards to EC or product design. |

### 5.3.9 Product maturity status

Table 9 shows the challenges that can be expected when products are not mature that normally undergo several EC in their product lifecycle.

**Table 9: Challenges with immature products**

| Respondents | Theme, remarks or challenges |
|---|---|
| P7; P9; P11 | (Competency and skills) When products have not been field tested, there may be a tendency for more EC because the product definition is undergoing more development than it would for a more mature product. |

### 5.3.10 Challenges with collaborative software tools

Table 10 shows the challenges that companies may face with the use of collaborative software as tools for CPD.

**Table 10: Constraint due to use of collaborative software tools**

| Respondents | Theme, remarks or challenges |
|---|---|
| P2; P3; P4; P5; P7; P8; P11; P12; P13; P14 | (Process Frameworks – Commonalities) The compatibility of using different software platforms such as CAD systems to communicate the latest drawings or information. This can affect design performance between collaborative partners. |
| P2 | (Organisational alignment) Challenges include customers that would not allow the use of File Transfer Protocol (FTP) sites for transfer of data because of security concerns and those who do not use them because of their cost implications. |
| P2 | (Competency and skills) Not all personnel who may need to use collaborative tools are versed or have an understanding and awareness of the benefits and type of collaborative software systems that a company can use. |

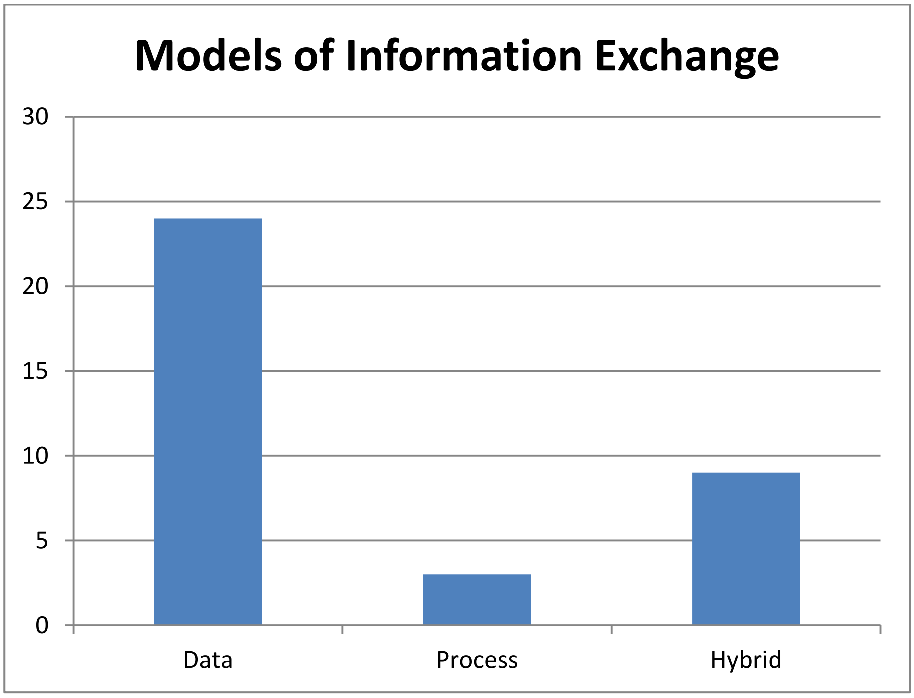
## 5.4 Research Question 2 - To what extent is the speed of EC affected by the nature of the information exchange models adopted?

Results for research question two are shown below for the extent in which the speed and flexibility of EC is impacted by the type of information exchange models chosen. The section showcases the type of information flow that companies make use that is conducive to particular environments. The reasons for adopting a particular model which are based on the openness of a company are also explained and the factors affecting EC are explained in detail, which are mainly due to challenges in information flow process and ECM internal processes.

### 5.4.1 Types of information exchange models

Figure 6 shows the different exchange models that the interviewees have used, with the data oriented information exchange models as the one widely used by the companies in this study.

**Figure 6: The information exchange model used by companies in this study**




### 5.4.2 Selecting information exchange models

Table 11 illustrates the factors to consider for selecting the process for exchanging information within a CPD environment.

**Table 11: Factor for selecting information exchange models**

| Respondents | Remarks and benefits |
|---|---|
| P7; P8; P10; P11; P12 | The type of information exchange model used in interacting with suppliers or customers for CPD can be determined amongst others by the maturity of the product, the product development stage and the complexity of the product. |

### 5.4.3 Challenges in openness of companies

It can be expected that not all companies are open to collaborative efforts and this is shown in Table 12.

**Table 12: Supplier openness to information flow processes**

| Respondents | Remarks and challenges |
| --- | --- |
| P4; P8; P11; P13; P14 | Not all suppliers are open to scrutiny of their processes and there is struggle to get information from them. |

### 5.4.4 Challenges in transfer of information

Table 13 highlights the limitations and concerns of using FTP sites to transfer data between companies.

**Table 13: Limitation in use of collaborative software tools**

| Respondents | Remarks and challenges |
| --- | --- |
| P4; P8; P11; P13; P14 | Not all companies have FTP sites or allow them because of security concerns, used to exchange information within supply chain. This means files can then be exchanged by means of memory devices that are couriered or by other physical means. |

### 5.4.5 Impacts of EC during production

EC are conducted at various stages in a product's lifecycle and Table 14 shows the challenges when EC are conducted during the manufacturing processes of products.

**Table 14: Factors leading to EC during production phase**

| Respondents | Remarks and challenges |
| --- | --- |
| P2; P5; P6; P7; P11 | Impacts of EC during production are on costs, schedule, impact on supplier and customer processes, contract obligations etc., and may be caused by production definitions not adequately addressed, customer's uncertainty and misinterpretation of requirements. |

### 5.4.6 Challenges in a long ECP process

The challenges associated with ECP process are shown in Table 15.

**Table 15: Perceptions about the ECP process**

| Respondents | Remarks and challenges |
|---|---|
| P2; P4; P5; P6; P7; P7; P8; P9; P10; P13; | There may be some risk in the ECP process being perceived as long and unnecessarily complex. This may cause frustrations and there may also be some ill-discipline in seeing the process through when confronted by urgent ECP or when the design time frames require some urgency. ECPs have been lost in the system in the past because of manual processes that do not have tracking capability. The ECP process has been derived when the times scales were not necessarily much of an issue to customers. |

### 5.4.7 Risks in shortcutting the ECP process

The ECP process risks are shown in Table 16.

**Table 16: Risk factors in shortcutting the ECP process**

| Respondents | Remarks and challenges |
|---|---|
| P2; P7; P8; P8; P9; P11; P13 | The current ECP process has been considered as very long but comprehensive to cater for all eventualities. However the risk is that the process is often speeded up and certain gates bypassed because of urgent requirements. This poses a risk that not everything can get covered. |

## 5.5 Collaboration requirements

This section shows what needs to be in place to ensure effective collaboration across enterprises. Table 17 shows what the interviewees' experiences and views are with regards to basic requirements for collaboration between a company and its partners.

**Table 17: Basic requirements for cross enterprise collaboration**

| Respondents | Remarks and collaboration requirements |
|---|---|
| P2; P3; P4; P6; P7; P8; P9; P10; P11; P12; P13 | Teaming arrangements, whether formal or informal, can facilitate better information flow for a company‘s supply chain and its partners |
| P2; P6; P7; P8; P9; P10; P11; P12; P13; P14 | A balance must be kept by companies in a CPD relationship to have internal expertise to corroborate information from customers and suppliers. |
| P2; P4; P5; P6; P7; P8; P9; P11; P12; P14; | It is imperative to involve your CPD teams early in the design processes for optimal success rates in design performance. |
| P2; P4; P6; P7; P8; P9; P10; P11; P12 | Collaboration requires CPD teams to have good, open relationship based on trust for success. |
| P2; P6; P7; P8; P13; P14; P14 | Support from the company‘s executive team for collaborative efforts facilitates CPD success. |

## 5.6 Benefits of collaboration

This section highlights the benefits that can be derived in using collaboration as a strategy.

### 5.6.1 Collaboration practices from partnerships

Experiecece of interviewees on how best practices in partnering help companies are shown in Table 18.

**Table 18: Collaboration gains across enterprises**

| Respondents | Remarks and collaboration gains |
|---|---|
| P2; P3; P4; P5; P6; P7; P8; P9; P10; P11; P12; P13; P14; | Collaboration leads to gains from customer competence and experiences for a company. Where partnerships are concerned a wide customer base can be established that enables a company to increase market share. |
| P2; P4; P7; P8; P9; P10; P11; P12; P13; P14 | Collaboration leads to gains in problem solving across the enterprises whether they be from suppliers or customers. |

| | |
|---|---|
| P7; P12 | CPD benefits include sharing of development cost where a company and its supplier can contribute towards the investigations and evaluations of products leading to a competitive edge. |

### 5.6.2 Benefits of supplier or customer development in a CPD

Table 19 shows the views of interviewees about developing the capabilities of a CPD network. It should be mentioned that customer development in this context refers to partner companies that defence contractors usually partner with in foreign countries as part of contract or tender requirements. These companies may not have the necessary manufacturing capabilities and are developed over time to offer these capabilities to the end user who is their customer, and they are customers to defence contractors.

**Table 19: Benefits that can be derived from developing collaborative partners**

| Respondents | Remarks and benefits |
|---|---|
| P4; P10; P13 | Development of suppliers or customers decreases reliance on internal resources and companies can concentrate on their core capabilities. |
| P8 | Supplier performance in terms of quality products, lead times and EC management can enable a company to react quickly to its customer demands. |

### 5.6.3 Benefits of using collaborative software applications

Table 20 below shows what the respondents illustrated as their experiences and opinions about the benefits that can be derived from using collaborative software applications. The software application systems will come in various forms from enterprise wide application to specific systems that are discipline specific like CAD systems.

**Table 20: Benefits that can be derived from using collaborative software applications**

| Respondents | Remarks and benefits |
|---|---|
| P2; P 7; P9; P11; P14; | Collaborative software tools make visualisation of drawings and design changes in real time easier as changes happen between collaborative partners. These features include discussing these changes from different geographical positions. There is a time saving benefit because the parties can sit in front of their computer together and move things around in real time as per design requirements. |
| P2; P3; P7; P11 | Collaborative software tools can ease cross enterprise collaborations for example when exchanging design files. Sensitive information can be easily transferred between the CPD networks depending on security requirements of companies. |
| P2; P4; P5; P11; P13 | Automated systems can ease storage and retrieval including tracking of information, and produce better quality of drawings that are accessed within networks from different geographies. |
| P2; P9; P7; P14 | Large files that cannot be sent by email can be sent through FTP sites thus increasing the speed in which information flows between collaborative partners. |
| P6 | Some of the advanced collaborative systems are enterprise wide system, meaning they can manage the real live data of the total enterprise, and not only for specific systems like CAD system. The benefits are that data can be promulgated directly to the supplier to speed up information flow. |
| P6 | The capability of the network to have common systems may enable companies to interact effectively and efficiently. |

### 5.6.4 Benefits derived from utilising prototype processes

Table 21 illustrates what the interviewees view as best practices that can lead to benefits in prototyping.

**Table 21: Benefits of prototyping as an ECM process**

| Respondents | Remarks and benefits |
|---|---|
| P8; P9; P10 | Prototyping benefits includes amongst others, having products within a short space of time that enables a company to conduct any necessary EC before the baseline of a product is fixed within the design phase environment. |
| P2; P9; P11 | Information can be made available from prototyping where changes made are tabled to ultimately simulate a near perfect scenario before a pre-production run is conducted. |
| P5; P14 | With prototyping, customers and suppliers can experience the product and give written feedback on the changes they want, thus an ideal process is set in place which is less risky. |
| P2; P14 | Prototyping stabilises the manufacturing and design processes where inadequacies can quickly be picked up and addressed. |

## 5.7 Best practices in ECM and CPD

This section is about how some of the best practices that were identified from the interview process can be used to try to resolve the research questions.

### 5.7.1 Limiting customer involvement to conceptual phase

Table 22 is about the best practices when customer involvement is limited to conceptual stages in a CPD.

**Table 22: Trade-off to limiting customer involvement to conceptual design phases**

| Respondents | Remarks and benefits |
|---|---|
| P2; P3; P7; P10; P11 | The involvement of the customer is on the conceptual phase rather than on the detail design where a company can try to limit them in this phase It include defining the user requirements and having dedicated teams that collect and report on the user requirements and feedback reports from customer experiences on prototypes. The customer is kept involved enough that they feel like they're part of the process but not too involved where they may hold up the design and manufacturing process. This involves showing them framework of the products where it will fit in order to help them visualize the whole layout. |
| P2; P3; P6; P8 | As a supplier there is need to understand the early stages of a process or product lifecycle so that you can influence these processes to your benefit. By understanding this, then, your products can be modified earlier to fit the customer needs resulting in a competitive edge. It sometimes seems that customers mostly want to change things most of the time so understanding the product lifecycle to your benefit may be a competitive edge. |
| P11 | Customer involvement in the conceptual phases can benefit a company because savvy customers can transfer their best practices into a company. Their experiences of your product can be incorporated into future design so that new and current products can be designed right the first time around. |

### 5.7.2 EC processes

Table 23 is about best practices of ECM from the interviewees.

**Table 23: Views about best practice in ECM**

| Respondents | Remarks and benefits |
|---|---|
| P2; P3; P4; P5; P6; P7; P8; P9; P10; P11; P12; P13; P14 | ECM is a controlled process that needs to be understood by all stakeholders in the company. In the companies reviewed, every change undertaken is made with an ECP process be it in product definitions, documentation or software, and is regarded as a highly important part of conducting business. The ECP emanate from within and outside the company and are classified according to how they impact the customer. Class 1 ECP which affects the customer needs customer approval, and Class 2 Design is an iterative action therefore ECPs must be expected and managed by the different parties involved, because they need to be approved to be accepted within cost. |
| P2; P4; P5; P8; P10; P11; P12; P13; | Best practices in EC include setting up a configuration control board (CCB), which is a board that involves parties on whom the changes have an impact and that ensures that all dependencies affected by the change are catered for and ECP are completed. |
| P5; P6: P7; P11; P14 | EC must be managed within a certain scope and within certain parameters according to the boundaries of the contract obligation to ensure there is an understanding between a company and its customers. The processes should include design reviews on the products and a company needs to be quicker and cheaper than its competitors in executing EC to remain competitive and to meet customer requirements. |
| P4; P8; | Changes affect product baselines, parts catalogues, spares ordering and legacy drawings which companies need to cater for and determine who funds the updates. |

| | |
|---|---|
| P3; P7; P9; P14 | ECM systems need to be able to have quick tracking and retrieval processes for data and information. The systems should enable a company to adapt to changes and new opportunities as quickly as possible and be measurable for effectiveness. |
| P6; P10 | Companies need to be able to manage the technical risks that come with change by proper qualification and formalised processes to make sure that the designs and processes they want to put in the market work. |

### 5.7.3 Flexibility in systems

Table 24 show the views and experiences of interviewees for incorporating flexibility in EC processes and systems to respond quickly to customer demands.

**Table 24: Allowing for flexibility in systems and EC processes**

| Respondents | Remarks and benefits |
|---|---|
| P2; P5; P6; P7; P9; P10; P12; P13 | To have systems in place that allow for flexibility in processes where parallel processes can happen concurrently in designing, prototyping, EC and production in order to meet customer deadlines and react quickly to customer demands. |
| P7; P9; P14 | An ability of a company to be agile to adapt to specific customer requirements, by offering various variants of products that are customised to needs of the customer, the mission profile of the products and the qualities required be it low or high volumes. |
| P4; | Flexibility of suppliers in handling EC quickly enough to meet deadlines. This flexibility can be a factor used for supplier selection and reviews. |

### 5.7.4 Best practices in prototyping

Table 25 shows the views of interviewees on how prototyping can be used to address EC in getting product definitions to be clear and manage customer expectations.

**Table 25: Best practice for managing EC by prototyping**

| Respondents | Remarks and benefits |
|---|---|
| P5; P7; P8; P12 | Project managers can schedule meetings with stakeholders to create awareness of progress during prototyping processes, and to discuss and assess required changes so that product baselines are managed and changes tracked expediently. |
| P2; P4; P7; P12; | Preparation and management of prototypes is important to ensure that all the performance measures that need to be captured from the manufacture and testing phase of the prototype is adequately conducted. This will help in resolving issues of uncertainties and addressing product definitions, bearing in mind the cost and delivery requirements. |
| P2: P4; P7 | By removing bureaucracies in the systems the prototyping process can be made simpler and quicker having with dedicated personnel and resources to conduct the work. This will ensure that a company can adapt to market conditions very quickly where a lot of information is captured for proper design definitions and to try to eliminate changes when the production stages happen. |

## 5.8 Improvements in collaborations and information flow

Table 26 shows what interviewees regard as important to improve collaborative efforts, ECM and information flow.

**Table 26: Suggested improvements by interviewees**

| Respondents | Remarks and improvements required |
|---|---|
| P2; P4; P5; P6; P7; P8; P9; P10; P11; P12; P13; P14 | (Process Frameworks – Commonalities) Companies can identify and improve on the internal alignment issues to maximise on the benefits brought about by collaboration. Internal processes, procedures and best practices can be refined and adopted, including the change in mind-set to embrace the changes brought about by making use of collaboration as a strategy. |
| P2; P4; P6; P7; P11; P13; | (Process Frameworks – Commonalities) Improvement of company processes can be conducted through training guides. Contracts can be structured better and implementation process of lessons learned from projects can be better utilised. |
| P2; P4; P6; P7; P8; P10; P13 | (Process Frameworks – Commonalities) Improvement in the use of collaborative software applications may lead to better communication. |

## 5.9 Conclusion

The research finding from the above tables and the figures are discussed in detail in chapter six to illustrate the connection between the findings, the literature reviewed in chapter two and the research questions.

# Chapter 6: Discussion of results

## 6.1 Introduction

Companies in the land systems sector of defence maintain high levels of investment in human capital in line with the industry norms. They mainly operate within low volume production environments, as opposed to the automotive industry where volumes are higher. This is unique because the land systems sector offers Commercially Off the Shelf (COTS) and customised products which they need to support over the product lifecycle (Bitzinger, 2003). The environment is characterised by the need to continually develop suppliers because of tender requirements from government acquisition agencies and in some other cases the inability to attract some of the more mature companies that operate within the high volume manufacturing sectors who may not be keen to supply low volumes of customised products.

Subsequently, whilst this research was being undertaken, LSSA announced a restructuring process to be conducted due to the reductions in defence spending. The reduced customer orders that they foresee to continue for their company will result in a 43 percent drop in sales for the 2014 financial year and a further drop of 25 percent in the 2015 financial year. The business unit mainly affected is its vehicles division OMC, whilst the other two units - Gear Ratio and Dynamics - that are smaller financially relative to OMC will see modest growth. The skill set required to move the company for the next two years are being reviewed in accordance to a structured value system. Some of the implications of the restructuring are that those affected by the reductions may have also established relationships with suppliers, subcontractors and customers, which may affect the collaborative relationships in the short term. This, again, emphasises the importance of this study showing the dynamism within this segment.

Conversely, Armscor awarded a multi-billion rand contract to Denel Land Systems (DLS) at the end of September 2013. The contract will see DLS produce 200 armoured military vehicles as a lifeline for the state owned entity and supporting industries (SAPA, 2013). The emphasis in this contract is on the stringent conditions for ensuring local content and supplier development, which are initiatives by Armscor and the South African government (SAPA, 2013). Two thousand direct and indirect jobs are expected to be retained and created from this contract, but it should be emphasised that the overarching strategic direction is collaboration (SAPA, 2013).

## 6.2 Research Question 1 - What are the key constraints to design performance in the context of the South African land systems sector of defence?

Five key constraints were identified in chapter five which highlighted and confirmed the theory from chapter two about the challenges for effective collaboration stated by Farrant and Mommeja (2009), namely motivation of partners, competencies, business value, commonality of business processes and organisational alignment. These findings showcased that these are issues that need to be identified and resolved effectively within collaborative environments. As they affect a product‘s functionality they have a ripple effect on the product quality, product cost and the time to market.

What is of significance from the findings is that motivation for collaboration scored lower meaning that companies may be increasingly making use of CPD as a strategy. The concerns however, are on the skills and competencies which scored the second highest, indicating the need to have programmes and guidelines for companies to carry out collaborative strategies. The second concern is on the commonality and minimal levels required for information flow and business processes to be aligned internally and externally for effective CPD. From Figure 5 of chapter 5 it can be seen that business processes scored the highest, therefore it may be the area where there should be focus and opportunities for evaluations and improvement.

### 6.2.1 Context of the land systems sector

In the introduction of this chapter it was mentioned that Armscor awarded DLS a contract for 200 vehicles, which by the standards of the automotive industry is regarded as low volumes. Table 1 and Table 2 of chapter five highlighted the challenges of operating in such an environment, where concerns include pricing and support for customer products. It was highlighted in chapter one and two that this sector is faced with defence cuts and recent economic pressures, so the volumes in the industry may remain relatively low (Bitzinger, 2003; Vermeulen, 2013; Deloitte Touche Tohmatsu Limited Global Manufacturing Industry group, 2013). This was also highlighted by the LSSA-OMC division which is restructuring because of economic pressures, whilst DLS which is a state owned may have been given a lifeline as part of Armscor's mandate to ensure the South African defence landscape remains competitive.

Part of the mandate for DLS includes supplier development, which is enforced as part of the awarding of the contract. Table 2 highlighted supplier development as an imperative in this sector, not only as part of the contractual obligation, but as an imperative for survival in this industry because of land systems defence contractors' inability to attract mature suppliers who may not be keen to supply low volumes.

Customer expectations with respect to quality products have not changed, thus the landscape is increasingly competitive amongst defence contractors and profit margins are under pressure. Figure 5 also highlighted that this is a dynamic environment with multiple forces, and therefore to operate in such an environment requires strategies that will ensure long term sustainability by managing the collaborative partners and activities better.

### 6.2.2 Enabling collaboration for effective design performance

To reiterate, design performance was based on several attributes including a product's functionality, form, fitness, time to market and costing structures. A collaborative environment has been shown to be complex as illustrated in Table 3 to Table 10 of chapter 5, having multiple actors and multiple forces across enterprises. Various challenges were identified, ranging from customer and supplier integration processes to information flow issues, organisational alignment issues and business processes for enabling collaboration. However Bititci et al. (2004) stated that implementation of collaborative initiatives requires a lot of effort, starting from strategic, operational and tactical levels, but when well executed, the collaborative benefits outweigh the difficulties.

#### 6.2.2.1 Collaborative challenges

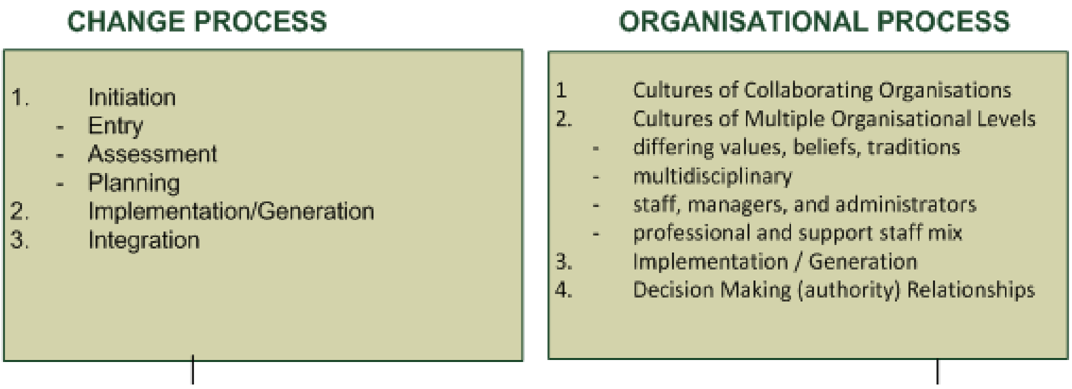
From Table 4 it can be seen that the complexities that come with management of suppliers to make collaboration work requires a comprehensive, multi-dimensional approach. Critical areas to be addressed are talent or a workforce that is competent to meet cross enterprise collaborations, top management with collaborative skills to guide the organisation, addressing the culture or business value systems of the organisation, and the organisational structure or alignment that will enable member organisations to collaborate (Farrant & Mommeja, 2009; Martzall, 2006; Silverstone et al., 2012). These critical areas were also shown in Table 4 as those challenges that need to be addressed. Table 4 further highlighted and confirmed the theory on the challenges faced by collaborative partners and the need to overcome these challenges by the companies studied.

The issues that were tabulated in Table 3 and Table 5 to Table 10 are extensions of Table 4 and were addressed in a multi-dimension problem solving approach described above. In essence, the area that needs the most focus and attention as highlighted in the research findings is in the business processes which are used to enable collaborations.

### 6.2.3 Multi-dimensional approach to collaboration complexities

Figure 1 in chapter 2 is an example of a model for collaborative research that was developed by LeGris et al. (2000) to try to address the complexities of a collaborative environment. Two of its sections have been extracted for easier reading when discussing the model, see Figure 7 below. LeGris et al.'s (2000) concern at the time was that most of the literature then was focused mainly on the benefits of collaboration. They had found that models and framework that help in implementing a collaborative strategy were lacking hence their study. By understanding the key constraints in the land systems sector, it then becomes important to look at how to overcome them to ensure that the benefits of CPD are realised.

**Figure 7: Extract of LeGris et al.'s (2000) model of collaborative research**




LeGris et al.'s (2000) model can be used to address the key constraints in the land systems sector by adopting and customising its multi-dimensional problem solving approach. Table 17 of chapter five shows what the interviewees regarded as requirements to be undertaken before a collaborative strategy is adopted. This information is part of the inputs that are required in addressing the complexities of CPD in the initiation phases when making use of guideline from LeGris et al.'s (2000) model for implementing a better collaborative structure.

Table 18 is about the benefits that can be derived from a collaborative environment; this information is used as motivation for the change management processes when addressing the organisational processes as shown in Figure 7 above. Research question one cannot be addressed in isolation without research question two because of the linkages between the two. However, what has been illustrated above is the approach that is necessary when key constraints have been identified and where they would fit as part of a multi-dimensional problem solving approach in a complex collaborative environment.

### 6.2.4 Conclusion of research question 1

Key constraints identified for design performance in a collaborative environment such as the land systems environment confirm what is in the current and previous literature. What this research highlighted was the industry specific challenges and the approaches that can be used to overcome them, however the commonalities and the approach can be used in other industries as well.

## 6.3 Research Question 2 - To what extent is the speed of EC affected by the nature of the information exchange models adopted?

Figure 6 of chapter 5 shows that the most widely used information exchange model the interviewees have utilised in their projects is the data orientated information exchange model. Data models represent 67 percent of the type of information exchange models adopted by companies in the study, followed by hybrid models at 25 percent and the process orientated model represented in just 8 percent of the projects.

What these figures point towards is that the companies studied may still not be at the point where there is full integration between collaborative partners and a more conservative approach is being utilised. The challenges of information flow and business processes which scored high in Figure 5 may indicate a direct link of why this is the case. The reasoning is that if internal business processes and internal expertise in a collaborative environment are not yet fully mature, then the data model may be the best choice to utilise as an information exchange model.

### 6.3.1 Factors for selecting the type of information exchange model

Table 11 shows the factors that were identified for selecting one model over the other, which were based on product maturity, complexity, and where the product was with regards to its development phases. For example, the more complex products may require a high level of involvement between collaborative partners and thus a process orientated information exchange model may be required. COTS that are normally selected by designers from product catalogues based on their specification would typically fall in the data model categories. Another example identified was the role product maturity plays in selecting the model of information exchange. In the initial development phase of products, a process model may be chosen and as the product matures and its product definition become clearer, a data orientated exchange model becomes applicable. This is an example where a hybrid model is adopted based on the two scenarios explained above.

In section 6.3 above it was also alluded to, that the reason for choosing a certain model may also be influenced by the maturity levels of the business processes that enable interaction between two enterprises. The maturity levels refers to existence of policies and practices within the company for enabling collaboration and how they have been used by the workforce. If the policies and procedure concerning business processes are well defined and clear, then the choice of the information exchange models also becomes easier. Integration becomes easier with well-defined procedures and policies so which are important for all information exchange models but more so for the process orientated information exchange model.

### 6.3.2 Openness of companies

Table 12 and Table 13 of chapter 5 set the context about the operating environment that can be expected by any company adopting CPD as a strategy. Not all suppliers may be geared for collaboration, sharing of information or be open to their processes being aligned with another company to enable flawless information flow. Although the motivation to collaborate scored lower in Figure 5, where it may be inferred that the companies which are not open to information sharing fall in that category, it may be that those that are not open may be critical to the success of a company's performance. The openness of a company will influence the speed with which EC are impacted and therefore it is important that the factors impeding openness are evaluated.

A lack of integration with supplier companies at the level required by buyer companies as suggested by the interviewees may be due to the difference in business values or cultures between the two enterprises. One of the examples highlighted by an interviewee was when a member of a supplier company resigned and a new employee had to fill in the gap who did not have a history with the buyer company, and issues of trust needed to be re-established. However, Smals and Smits (2012) found that the supplier's perspective about their willingness to help buyer companies in innovation depends on three potential value sources, with the first one being financial payments based on the sales volume and the product development associated with it. The second value source is the competencies in terms on technological knowhow towards product design, and the final value source is the reputation associated with doing business with a leading company. These are very important dimensions that need to be factored in when adopting a collaborative model and the type of information exchange model to be used, as they are able to influence the speed and flexibility of a company and its profitability.

In the land systems sector where there are customised and innovative products, payments towards development of products is therefore important as part of supplier development. Upfront fees may facilitate relationship building and trust as a show of commitment toward development projects to supplier companies.

Danese (2013) has also found in her research that supplier integration significantly and positively affects the buying company in terms of three important factors relevant for the land systems defence sector, namely efficiency, schedule attainment and flexibility. Defence contractors operate in a project management environment (Bitzinger, 2003; Farrant & Mommeja, 2009) whose basic foundation is cost, schedule and quality, meaning that supplier integration is critical to their performance. This also indicates that the type of information exchange model adopted may have huge implications on a defence contractor's performance.

Danese (2013) has shown that when there is coordination between buyers and suppliers as part of a unified system, the benefits that can be derived include cost reductions, better inventory control, better quality of products, and most importantly for any two companies in a collaborative environment, an increase in profitability. The implication for the defence contractors that have been studied or any other company may be for a shift from data orientated information models towards the hybrid models that have the option of full integration where required, and data models where EC do not have much effect on one company's processes.

### 6.3.3 Addressing the challenges of EC

Sections 6.3.1 and 6.3.2 set the context and are a guide in understanding the operating environment. When challenges or issues are raised, they need to be resolved with this context in mind for effective solutions to be implemented. Table 14 - Table 16 of chapter 5 are about specific challenges in EC processes; Table 14 is about the factors associated when conducting EC when products have been designed, qualified and something may have gone wrong. EC are then carried out during the production phase which is not ideal because of cost and schedule implications. The causes of EC in such instances may be uncertainty or misinterpretation of customer requirements in the conceptual phases.

Table 16 examines the length of time it takes for the ECP process to be completed, which has been highlighted by some as an inhibitor in meeting market needs. This leads to the process being speeded up as explained in Table 17, where certain processes are bypassed which also carries some risk. The ECP process has been viewed as sufficiently comprehensive to cater for all eventualities, but rather cumbersome because it is a paper-driven, manual process. The formalised paperwork may not be completed due to time constraints and pressures, although the physical EC may have been carried out. This is what may happen when a process is manual and paper-driven where tracking issues are problematic. A balance is required to cater for all eventualities as mapped out in the process, and to have some flexibility in speeding up the process as and when required. Automated systems may be the answer to such problems and at OMC where EC are prevalent, such a solution is being implemented in phases as resources allow.

### 6.3.4 Extent of information exchange models on speed of EC

To answer the second research question it is important to also understand the context of the operating environment. Firstly, the results have shown that the data orientated information exchange model is the most widely used model and that may not have been incidental when the operating environment is taken into context. In section 6.2.3 the operating environment was described where the issue of openness by companies was described because it influences information flow and sharing between collaborative partners. When there are teaming agreements and non-disclosure agreements and issues of trust are sorted out, the level of information flow becomes easier and better. This was established in the research findings and therefore it can make decision making easier on the choice of the information flow model.

Process orientated models have higher levels of integration and require high level of openness and information sharing and that will impact the speed in which EC are handled. It can therefore be inferred that if the level of openness is low, the impact of EC will be more pronounced on process orientated models than data orientated model. This is because in the process orientated model there is joint decisions making, evaluations and technical elaborations that must be agreed upon by the collaborative partners (SASIG, 2009). On the other hand, according to SASIG (2009) data models are not that much integrated and the information is shared as requested, with independent decision making so that once the information is received from the collaborative partner, the speed of EC will be depended on the recipient company's processes.

The second factor to consider that affects the speed of EC is from the collaborative applications and processes. Process orientated information exchange models are more suited to automated systems and high level of connectedness for ECM processes rather that paper driven manual ECM processes. Common systems where information can be stored accurately and there is visibility between the partners may enable EC to be speedily processed. Manual driven process where visibility is affected can be challenging in terms of retrieval and tracking thus affecting EC resolutions. Data orientated models are independent systems and are less impacted by collaborative application as compared to process orientated models.

The third factor that impacts information exchange models is from business processes that need to be well defined and clear. Process orientated models are best suited in companies where organisational alignment processes that enable interaction between collaborative partners are clearly mapped out. Ideally, the internal process must be effective and efficient before a collaborative strategy is adopted because if not, that may lead to chaos in the company. This will also eliminate confusions and frustrations as in the research finding from Table 15 where the ECP process was deemed to be too long to get things done. If a partner is involved then it becomes more of a challenge and the speed of EC is affected.

### 6.3.5 Multi-dimensional approach to ECM & collaboration complexities

**Figure 8: Extension of LeGris et al.'s (2000) model customised for CPD and ECM processes**

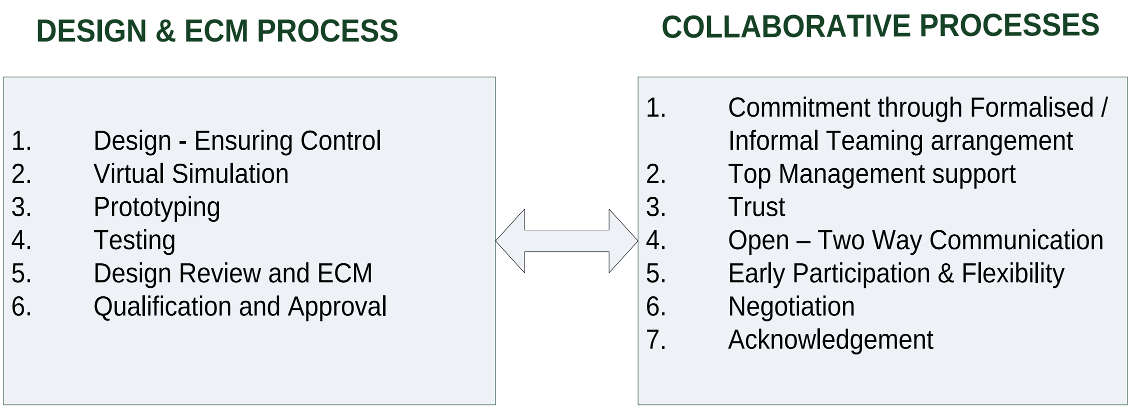



Figure 8 shows an extension of the LeGris et al.'s (2000) model that was developed for collaborative research implementation in the hospital service sector and now customised and extended for a CPD environment in the land systems sector. The model is part of a multi-dimensional approach that is necessary when implementing a collaborative strategy that the design and ECM processes need to be able to interact in collaborative processes. The intention is to create an environment where these processes can interact effectively and flexibly according to the organisational alignment principles and information flow becomes flawless between two organisations.

Table 22 to Table 25 of chapter five are about best practices in design and ECM within a collaborative environment. Before embarking on a CPD strategy the internal processes must be clearly defined and then defined for external parties when a collaborative strategy is to be implemented. Table 22 for example examines the best practice in the design stages of what a company needs to undertake with respect to customer involvement who may be collaborative partners in designing a product. It defines the process clearly on where the cut-off line is with respect to customer involvement, with some flexibility, agreements are clear and information flow between the parties can be shared as negotiated and agreed. What has just been described is showcased in Figure 8 with the design processes (Design – Ensuring Control) on the left that are interlinked with the collaborative processes (Agreements & negotiations etcetera) on the right which are used as guidelines when adopting and implementing CPD strategies in line with a company's practices.

The same process can be followed as explained above about the linkages between design and ECM processes with the collaborative processes when setting up the guideline for best practices internally with respect to ECM processes discussed in Table 23 to Table 25. The emphasis is to have the internal processes clearly mapped out so that there is no ambiguity when the collaborative processes are implemented for CPD.

### 6.3.6 Conclusion of research question 2

The context to the research problem was first examined based on the research findings from chapter 5, Table 11 and Table 12. Knowing the operating environment, it becomes easier to understand the influences that affect the speed of EC in relation to the information exchange models which were explained. With this information it was also shown that a multi-dimensional approach in addressing EC issues and implementation of CPD is necessary. The approach need to take into account the key issues that were explained in section 6.2, of business processes which featured prominently, followed by skills and internal expertise.

The role of change management is important in the implementation of CPD where there may be resistance to CPD as a strategy from those who do not realise its benefits. The competitive environment in the land systems sector requires a change in mind-set towards CPD so that the shift from the conservative data orientated model to ones of full integration may be realised. This shift will be discussed in the concluding chapter as part of the recommendations.

# Chapter 7: Conclusions and Recommendations

## 7.1 Introduction

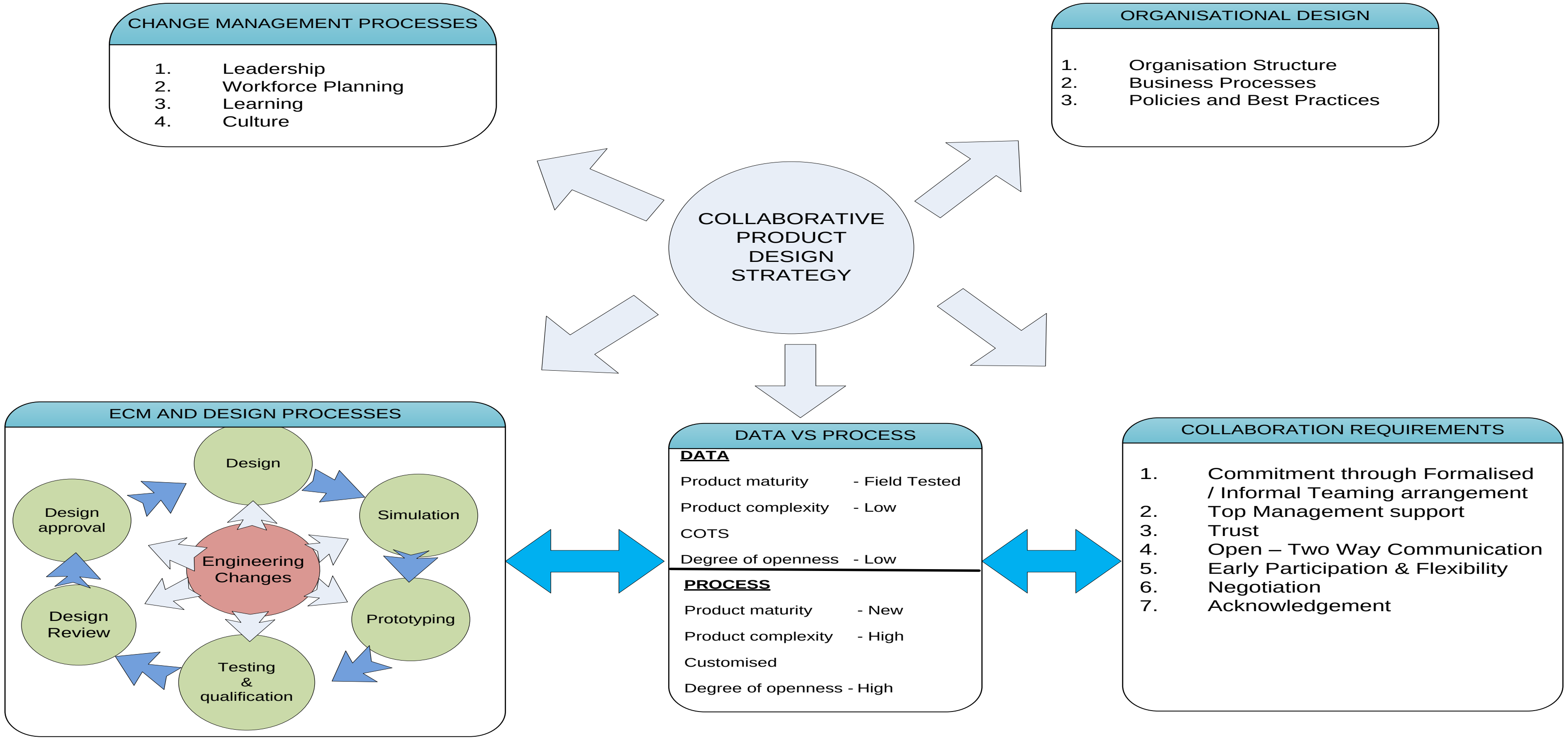
CPD can be adopted as a strategy by companies faced with competitive pressures and those that are looking at sustaining or even exceeding their market position. Companies in the defence land systems sector have been using collaborative strategies in the design of customised and complex products to meet customer requirements. Production volumes are lower in this environment and the complexities of conducting business include challenges in organisational alignment, collaborative processes that need to be reviewed and re-evaluated constantly, suppliers that may need to be developed, workforce expertise and leadership skills mapping for CPD strategies and information flow challenges. Information storing, retrieval and speed of information flow between collaborative partners is pivotal to the success of the CPD strategy. The use of collaborative software application is becoming more pronounced and the trend may be moving towards those collaborative software applications that can be incorporated with enterprise wide applications.

On the other hand, EC in any sector are unavoidable and when effectively managed they are able to be beneficial to a company. Innovative companies view EC as a cost benefit and as opportunities in designing leading edge products by understanding that design is an iterative business process that will make their products more reliable and even exceed customer expectations. When EC are managed, they may make use of automated systems that ease with electronic tracking, storing and retrieval of EC or manual to semi-automated systems where tracking and retrieval may take longer than if automated. In a collaborative environment ECM becomes complex and thus this research was looking at constraints in the land systems sector of defence in South Africa. The extent to which information exchange models influence the speed of conducting EC was also evaluated through the experiences and views of engineering managers.

## 7.2 Collaborative product design model

This research project was aimed at evaluating and understanding the constraints and context so that a model can be derived from the literature reviewed and from the research findings as illustrated in Figure 9.

**Figure 9: A collaborative product design evaluation and decision support model**



Why the need to evaluate the operating environment? The approach taken was to understand that even though companies understand the benefits of collaborative strategies, they are still faced with challenges in issues of openness and business processes that are still not well supporting collaborative initiatives. By evaluating these constraints the root causes can then be resolved. In chapter 6, it was described that a multi-dimensional is required in resolving constraints and issues for collaborating and thus the model in Figure 9 was designed as a evaluation tool to try to cover some of the important aspects for ECM as an enabler in a CPD environment. The model consists a of change management section to evaluate aspects of leadership and talent required for CPD. The business processes for enabling CPD were found to pose the highest challenges within the land systems sector. Their resolution needs to be addressed in conjunction with the change management processes.

The design process and ECM are shown in the ECM and design process section where EC can happen throughout the design process. The communication between collaborative factors can be through the data or process model where choices for the models are highlighted. Finally, the collaboration requirements for a company that wants to adopt a CPD strategy are explained in brief under the collaboration requirements section. It is important therefore that the operational policies and procedures be constantly reviewed for alignment with the CPD strategy. The research findings have in essence, shown that the area that needed the most focus is in the business processes in the companies studied was, which incidentally was also what the interviewees agreed was the area in need of improvements as tabulated in Table 26.

The model above in Figure 9 can be utilised by companies currently engaged in CPD as a check list and those that will be embarking on a CPD strategy. The relevance of this research project to academia is three fold; firstly on our understanding to CPD, secondly on information flow processes and lastly in ECM in isolation and ECM as part of a CPD strategy.

## 7.3 Recommendations for future research

The second key constrains that scored high from Figure 5 of chapter 5 was with respect to the skills and competencies required for a collaborative environment where it is increasing evident that companies are adopting collaborative strategies to concentrate on their core capabilities. However, buyer companies may still require some in-house expertise that is knowledgeable in supplier products to communicate and verify the buyer company requirements. For example, land systems defence contractor have their core capabilities in systems design, project management and integration and rely on their suppliers for subsystems designs that are critical for the operation of vehicles. They make use of in-house expertise at subsystems level to draw up customer requirements and communicate them to the suppliers. They keep expertise at subsystems level in developing and monitoring the performance of subsystems as part of the total vehicle requirements. The question is how, should buyer companies strike the balance between, keeping in-house expertise and making their suppliers subsystems responsible and still remain competitive. Are the huge investments in human capital in multidisciplinary personnel within a company, which has adopted a collaborative strategy, still relevant and justifiable when faced with economic pressures? What capabilities should buyer companies remain with? What kind of expertise is required at executive level to steer companies engaged in collaborative engagements. Are there any educational programmes geared for executives for helping companies in implementing and analysing the complexities that are brought about by collaborative relationships.

Secondly, the data orientated information exchange model was found to be the most widely used based on various factors explained in this research. If the landscape was changed and the process model was the widely used, then what key constraints would be found to exist? How open are South African companies to embark on collaborative strategies. Is there empirical evidence to statements that the degree of openness from South African companies is low and how will that impact

CPD initiatives? The two questions can add more towards our understanding of the South African landscape towards competitiveness.

## 7.4 Conclusions

The benefits of CPD were highlighted by the interviewees to include cross enterprise problems solving; gains from collaborative partner expertise and the sharing of development cost. Moreover, collaboration as a strategy can increase a company's footprint in new markets especially in countries where local content is a prerequisite towards the awarding of tenders where it is prevalent in the defence sector. The benefits in such instances are in the development of the local industries and the transfer of skills that is brought about by collaborative efforts. For suppliers, CPD offers them a way to evaluate and qualify their products through their collaborative partners. This gives their products credibility when marketed to new customers.

On the other hand, business processes such as ECM are important for any company involved in design and manufacturing. EC are able to lead to improved product and should be treated as such, a "way of life" in the words of one of the interviewees. They are central to design performance and therefore their impact in a CPD cannot be ignored.

Finally, a model was developed as an evaluation and decision making assistance tool for companies conducting collaborative strategy and in this case the emphasis was on ECM and information flow. Other business processes can also be mapped and customised using the model as required. The importance of the model is on a multi-dimensional problem solving approach required by any company that is evaluating its collaborative strategy or one adopting a CPD strategy.

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## Appendix 1

**Figure 10: Overview of global markets with greatest market for armoured vehicles**

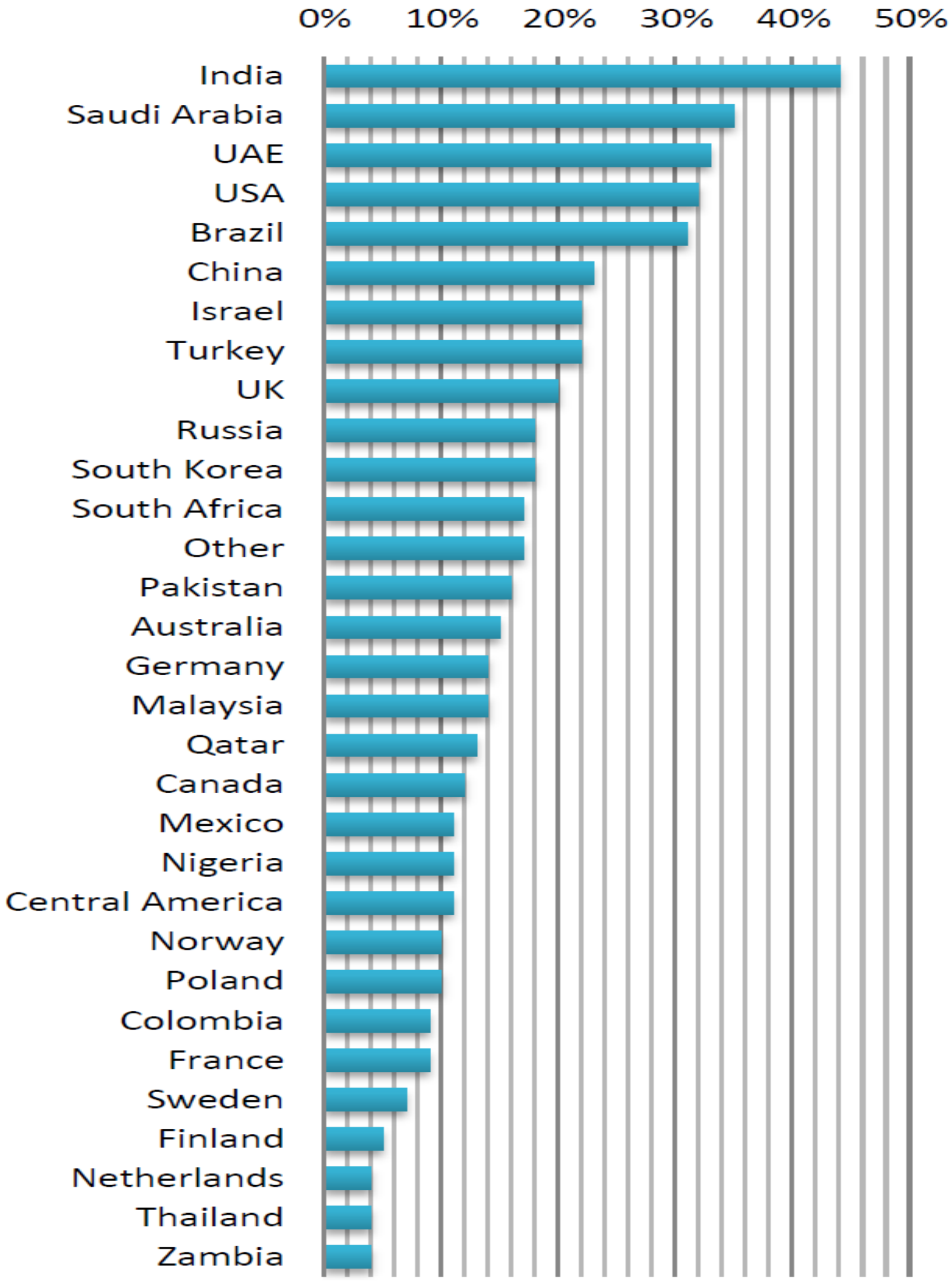


**Figure 11: Evolution of ARMSCOR**

Source: http://www.ARMSCOR.co.za/About/History.asp

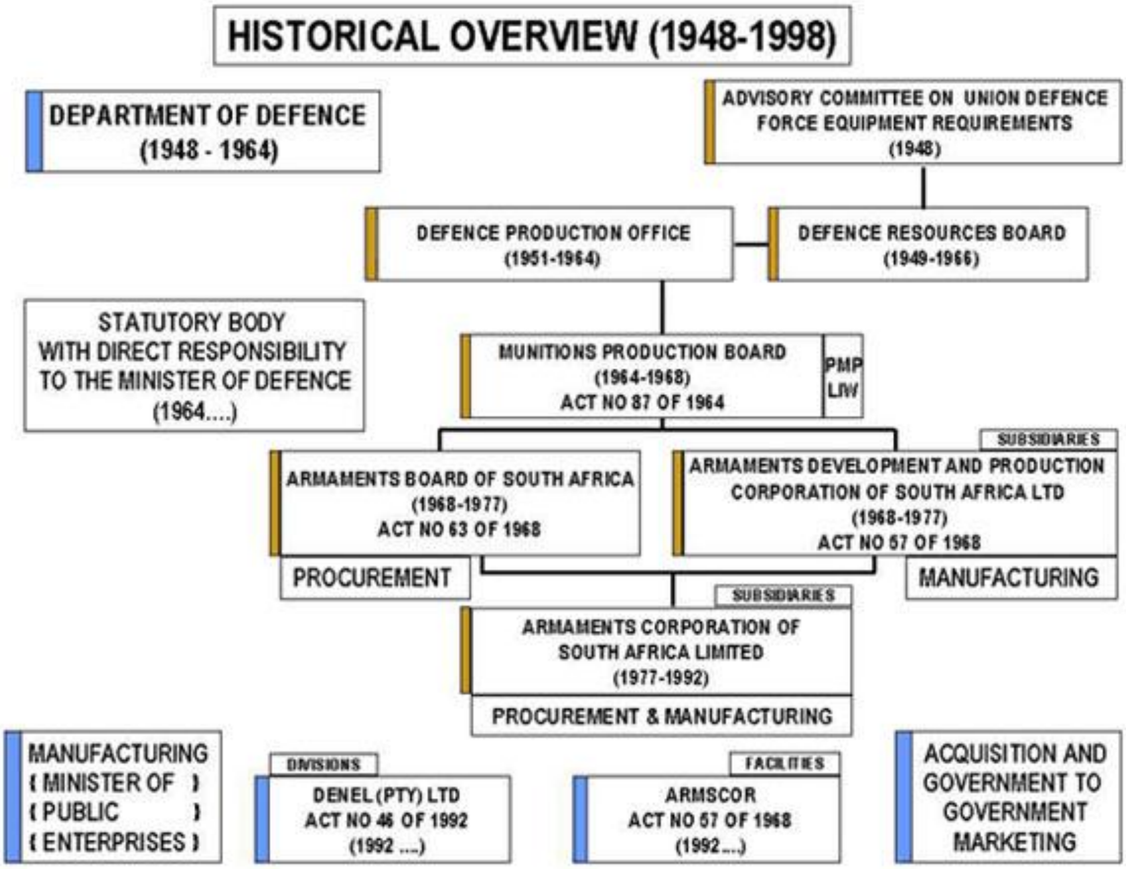
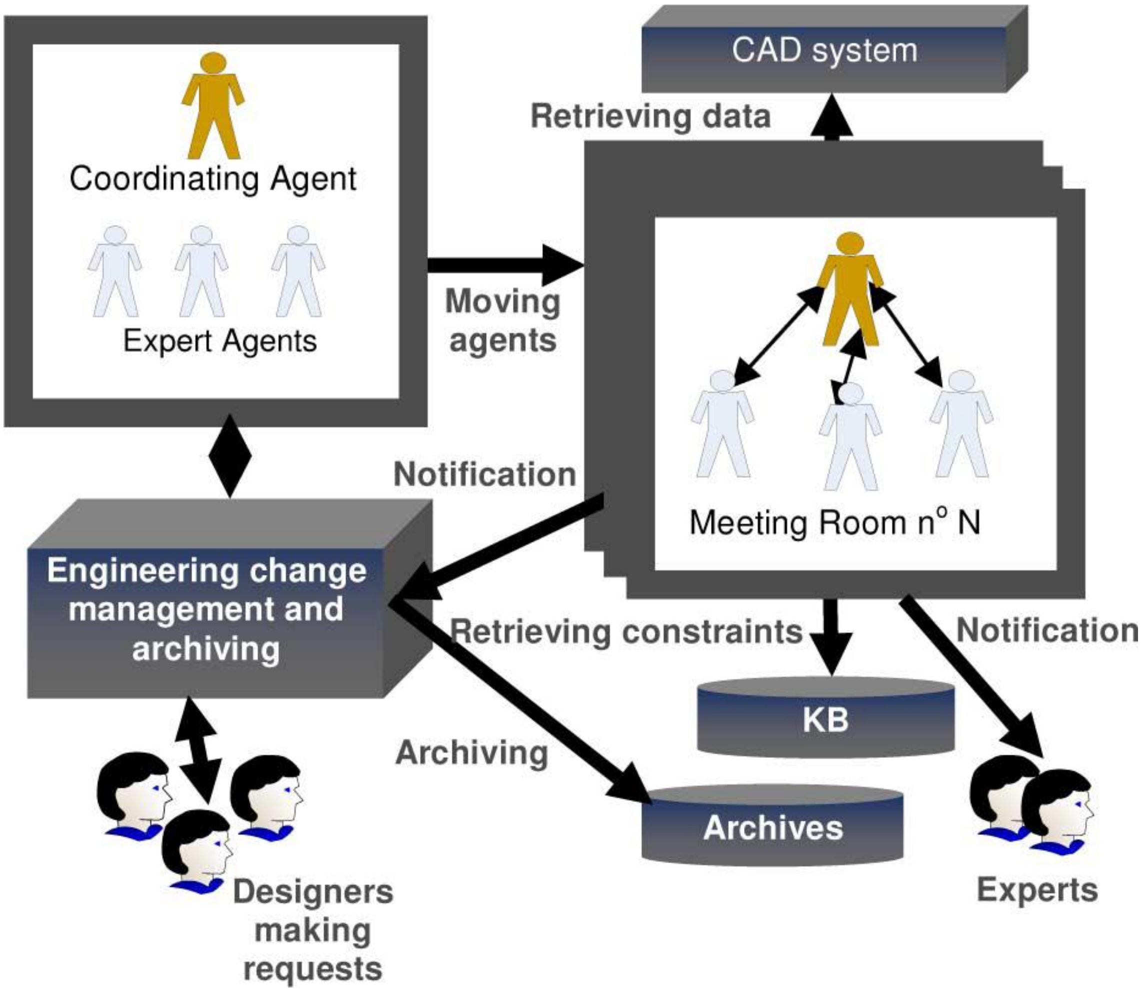


**Figure 12: EchoMag Architectural overview**




The system consists of the following:

- A coordinating agent tool for coordinating the work of expert agents in a CPD.
- An expert agents tool where an expertise in a specific discipline can be found and helps in the collaboration process.
- A meeting room in a form a computer or a collaboration site where different agents can meet and negotiate solutions to a problems.
- A knowledge base where the latest specifications and constraints on CAD products are kept and maintained. (Habhouba et al., 2011)

## Appendix 2

**Interview Guide**

**Setting the scene.**

The focus of this study was to establish how design performance is impacted in a Collaborative Product Design environment by information flow when engineering changes occur. Studies have shown that engineering change is important because it influences product lead time, cost and productivity and also because it manages an organisation's response to dynamic market conditions. However, its complexity increases dramatically when several companies are involved collaboratively. The interview will be structured around key themes which are collaboration, how information is shared, identifying constrains and best practices for innovation in engineering changes that ultimately will lead to a framework that companies can use for effective engineering change management when engaged in collaborative environments.

**Guide**

For record purposes please state your name and what you do in this company.

- What projects are you currently working?
- Can you tell me about your role in product development?
- Are there any teaming arrangements or partnerships at the moment in designing or marketing your products for your customers?
- Tell me more about them?
- Is there a specific timeframe to this arrangement?

**Supplier**

- Who are your critical suppliers or design partners that you collaborate with in designing products?
- Can you explain the relationship that your company has with these companies and how do you interact with specific reference to when you are designing products.
- Do you know how have they been selected and why?

Some background: Information can be exchanged in three ways, data orientated exchange model, process orientated exchange model or a hybrid model. Data is where information is merely requested for and supplied; process is more integrated because of design dependencies and hybrid model is a combination of the two systems.

- From the description above, which exchange model have you used when designing products with suppliers or design partners?
- Can you give examples and how the process works? For example what is your platform of communication with them with regards to designs?
- Where has there been challenges and what was done to mitigate them?
- Where do you see improvements?

**Customers**

- Explain the process when you receive a requirement from the customer.
- What is the level of interaction when it comes to designing products with the customer?
- What are their expectation and level of involvement when designing products?
- What kind of exchanges happens between your company and the customer?
- Please explain in more detail these exchanges.
- Where do you see improvements?
- Where has there been challenges and what was done to mitigate them?

**Engineering Changes**

- Explain the process of engineering changes in the company.
- Can you tell me about recent engineering changes that you had to do with your suppliers or design partners?
- Where have these changes emanated? How were they communicated in the company?

- Can you give examples where these changes had a ripple effect over other systems?
- How were they managed?
- Are there examples of product changes that were coming from the customer?
- How were they managed?
- What is your view on engineering changes and the management process?
- If a customer is to bring in a change in your product, how geared is your company to execute the changes and still meet the required deadlines
- What specific systems are you currently using?
- Are they manually driven or automated.

If manually driven

- How would you know if a design was previously changed and how would you track the changes?
- What is your experience with this system?
- Where do you see the future on engineering change management?
- Why have there been no changes on the system?

Automated systems

- Tell me more about the features of the systems?
- What is your experience with this system?

Improvements in ECM

- In your experience, how have your suppliers performed when it comes to product changes or upgrades?
- What value adds do you think can be done to improve on engineering changes?