E-MANUFACTURING – THE ROADMAP FOR SOUTH AFRICAN MANUFACTURERS

L. Nyanga[1*] and A.F. Van Der Merwe[2]
[1]Department of Industrial Engineering
University of Stellenbosch, South Africa
16763300@sun.ac.za

[2]Department of Industrial Engineering
University of Stellenbosch, South Africa
andrevdm@sun.ac.za

ABSTRACT

Globalization and the internet have given customers a wide choice of products to choose from and they are now expecting a lot from products. Customers are demanding more value, less risk and better integration of products hence products now have a shorter product life cycle. E-manufacturing can help companies to optimize the use of production assets, reduce production cycle times and costs to meet these customer requirements. The paper shows factors that influenced an economy to successfully implement an e-manufacturing model that transformed the economy from a struggling economy into an advanced economy. E-manufacturing models are discussed. Taiwan is used as a case study of how engineering chain can be utilized for SMEs to enjoy equally or even higher competitive advantage than their larger competitors by appropriately utilizing external networks. The situation in South Africa shows that the country can benefit from the growth of SMEs and e-manufacturing if networks and a culture of sharing information are built among SMEs and companies in the country.

[*]Corresponding author

1. INTRODUCTION

After the end of World War II, South Korea and Taiwan were no better off than the other struggling nations of the Third World. Today the two countries have advanced economies which have enabled them to be world leaders in manufacturing information technology. Their economic success stories have served as role models for many so-called developing countries. To achieve exceptionally high growth rates and rapid industrialization the two countries used imitation rather than innovation in developing hi-tech products. Companies would imitate products from developed nations, catch-up with the manufacturing capabilities of the advanced nations, produce the products faster and at a lower cost than the developed nations hence these nations have become a hub of manufacturing of hi-tech products. To enable the countries reduce production cycle times and costs they implemented e-manufacturing but followed contrasting approaches. South Korea used large industrial conglomerates whilst Taiwan used small to medium sized firms with an e-manufacturing model that does not only focus on the supply chain's "order-to-delivery" to deliver right quantity of right product at the right time and at minimum cost but also supports a fast design cycle. With significant contribution SMEs have made in job creation in the South African economy, South Africa can learn from the Taiwanese e-manufacturing model. This paper aims to show how South Africa is prepared to implement a successful e-manufacturing model like Taiwan. The organization of the paper is as follows: first we look at the definition and models of e-manufacturing, we then look at factors that enabled Taiwan to implement its e-manufacturing model lastly we then look at how the South Africa is prepared for the implementation of e-manufacturing.

2. E-MANUFACTURING

According to McClellan [44], e-manufacturing is concerned with the use of the internet and e-business technologies in manufacturing industries. It covers all aspects of manufacturing - sales, marketing, customer service, new product development, procurement, supplier relationships, logistics, manufacturing, strategy development and so on. AMR [2] defines e-manufacturing as:

> "*The core of [an] e-manufacturing strategy is the technology roadmap for information transparency between the customer, manufacturing operations, and suppliers. An e-manufacturing strategy takes e-business processes, such as build-to-order or reliability-centred maintenance and generates guidelines for implementing plant systems. The e-manufacturing strategy takes the e-business and manufacturing strategies and creates a roadmap for system development and implementation in the plant*."

Nof [49] describes e-manufacturing as part of the *e-activities* (i.e. activities based on and executed through information technologies as shown in Figure 1) which forms e-works. He uses the definition of e-work by the PRISM Centre:

> *Any collaborative, computer-supported and communication-enabled productive activities in highly distributed organizations of humans and/or robots or autonomous systems*.

Kovacs [33] uses the term internet "e" technologies which he says enable businesses to shift from an enterprise-centric to a customer-centric model.

V-Design	E-Business	E-Commerce	E-Mfg	V-Factory	V-Enterprise	E-Logistics	....
E-Work							

Figure 1: The scope of e-work as the critical foundation of e-activities (Source Nof [49])

2.1 E-Manufacturing Rationale

E-manufacturing integrates hardware controls, information systems, and advanced decision technologies such as Industrial Engineering, Operations Research, Artificial Intelligence, and Queuing Theory (Zhang et al [74]). Wang [68] states that e-manufacturing optimizes the use of production assets based on information exchange from shop-floor operations, across the enterprise, and to the extended supply chain. In order for e-manufacturing to be successful, it has to be supported by the internet and information technology (Lee [37]). It makes manufacturing to be flexible enough to meet customer expectations and/or adapt to market shifts (GMS [18]).

According to Ugarte et al [67], the major challenges faced in the semiconductor industry are (1) *cycle-time reduction, (2) yield enhancement (3) fabrication productivity improvement at all level*. MESA [45] states that e-manufacturing plays an important role in addressing these problems as it has a wide scope that includes the following:

1) Improved data availability to enable decision support and knowledge discovery.
2) Enhanced tools and applications to use data in making decisions about productivity optimization.
3) Expanded equipment control to support the implementation of decisions.
4) Superior communication channels outside the manufacturing operation to secure information.

Besides widely recognized benefits, such as significant reductions in costs, cycle times, process variances, and rework rates as stated by Bijan [5], one main benefit of e-manufacturing is the seamless integration of manufacturing information management—electronic management of products and orders on the manufacturing floor (Rockwell [56]).

Guerra et al [20] discusses how manufacturing companies utilize large amounts of knowledge to manufacture products and apply manufacturing knowledge to develop products according to customer requirements and to offer competitive prices. They propose a manufacturing knowledge model (MKM) able to overcome the short comings of the majority of manufacturing companies and knowledge based systems (KBSs). The use of e-manufacturing makes it possible for a company to achieve knowledge based value creation and manufacturing on demand as stated by McClellan [44].

E-manufacturing enables information exchanges among various plant level systems with business systems to eliminate data bottlenecks that can occur in conventional enterprise IT architectures (Kovacs [33]). In the e-manufacturing era, companies will be able to exchange all types of information with their suppliers at the speed of light. In addition, design cycle times and intercompany costs of manufacturing complex products will implode. Information on design floors will be instantly transmitted from repair shops to manufacturers and their supply chains (Cheng et al [11]).

2.2 E-Manufacturing Models

When modeling e-manufacturing, all conventional manufacturing functions of “what” needs to be done must be included. According to Kovacs [33], it is “how” these issues are resolved that provides the basis for e-manufacturing. Kulkarni et al [35] proposes an e-manufacturing model that integrates customers, e-commerce systems and suppliers into the manufacturing process to provide an internet-based strategic framework for the factory. The model concentrates on the how SAP can be used to integrate business into the whole of the supply chain. It does not include the Manufacturing Execution Systems (MES) which delivers information that enables the optimization of production activities from order launch to finished goods.

By abstracting office and plant floor information systems running in industry, Qui [55] gives a generalized enterprise wide information context model, which is illustrated in Figure 2(a). From the model, EMS fills the gap between office planning and plant floor manufacturing and makes it possible to have a real-time plant-wide view of critical processes and production status that are necessary for timely office decision-making and optimal factory manufacturing executions. EMS has the responsibility of real time responses (Baliga [4]). It records results of activities in the plant and feeds data to the office information systems and also takes in data from the office information systems as shown in Figure 2(b), ensuring that their information is acted in the plant.

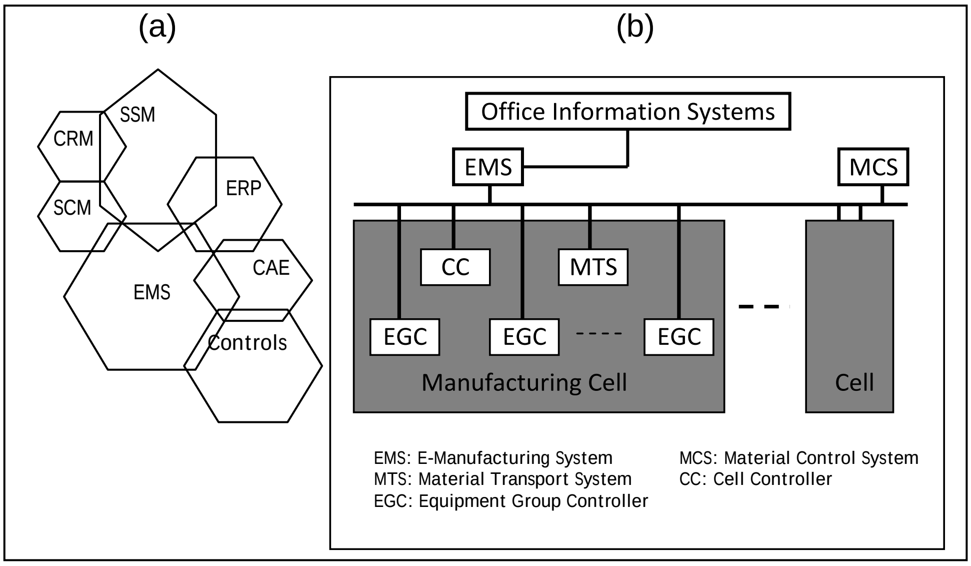

Figure 2: (a) Enterprise information model (b) Plant floor information model (Source Qui [55])

Koç et al [32] discusses how manufacturers are now under tremendous pressure to improve their responsiveness and efficiency in product development, operations, and resource utilization with a transparent visibility of production and quality control. The emerging applications of internet and tether-free communication technologies, is forcing companies to shift their manufacturing operations from the traditional factory integration philosophy to an e-factory and e-supply chain philosophy. E-manufacturing fills the gaps existing in the traditional manufacturing systems.

According to Lee [37], the link between Manufacturing Execution Systems (MES) and ERP is hindered by the lack of integrated information coming from and flowing to control systems on the plant as illustrated in Figure 3.

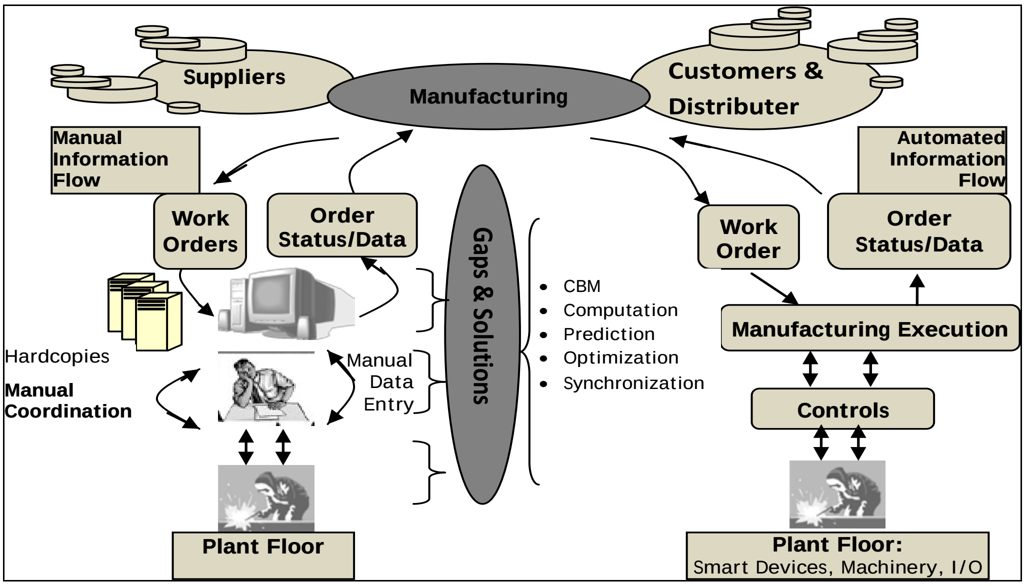

Figure 3: Gap in today's manufacturing enterprise systems (Source Lee [37]).

Lee [37] also states that e-manufacturing integrates all business elements including the all suppliers, customer service networks and manufacturing units through the effective use of web-enabled computational tools and tether-free technologies. E-Manufacturing has the ability to monitor the plant floor assets and enable real-time decision making by integrating manufacturing systems and upper-level enterprise applications, as shown in Figure 4.

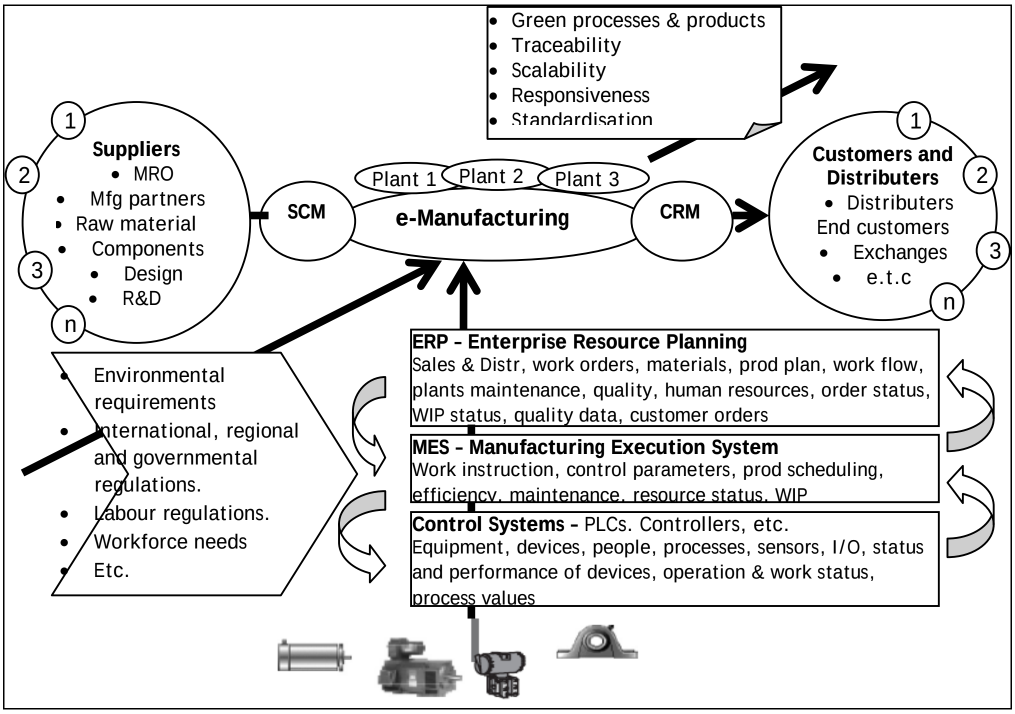

Figure 4: Integration of e-Manufacturing into e-Business systems (Source Lee [37])

Guerra [20] presents a model developed by ISMT, with a manufacturing and engineering portion show in Figure 5. In the model MES is responsible for the manufacturing system whist Equipment Engineering System (EES) is responsible for the engineering portion.

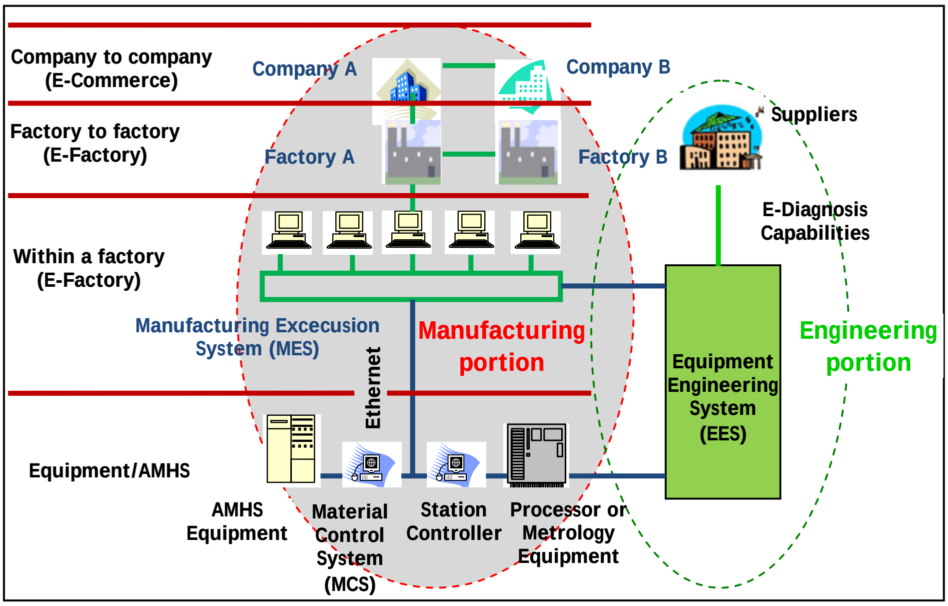

Figure 5: ISMT e-manufacturing hierarchy (Source Sematech [29])

One of the most used and successful models in Taiwan is the advanced e-manufacturing model presented by Cheng et al [11] shown in Figure 6. The model has four core components: manufacturing execution system (MES), supply chain (SC), equipment engineering system (EES), and EC. Whereas most of the models discussed focused mainly on the components of MES, ERP and SC, Cheng et al [11] added the engineering chain (EC) that deals with the time-to-market (T2M) issues. An engineering chain is a network of facilities and distribution options that performs the functions of a device design, verification of design, pilot run of manufacturing, assembly and test operations, device yield improvement and final release of mass-production.

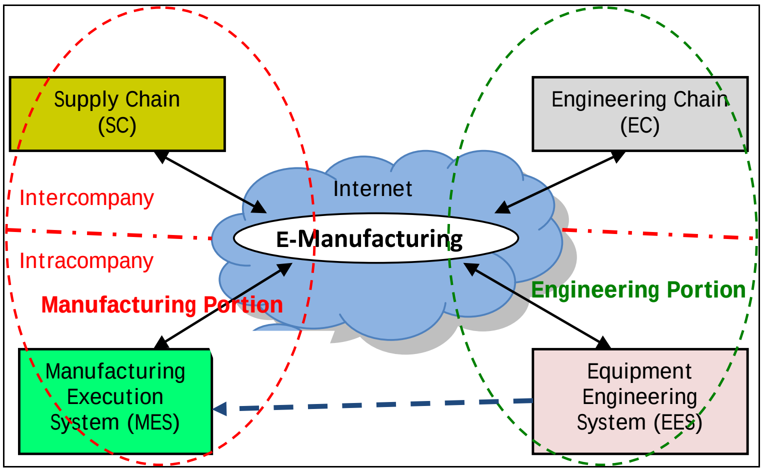

Figure 6: Components for the advanced e-manufacturing model (Source Cheng et al [11])

In the advanced e-manufacturing model, both the MES and SC belong to the manufacturing portion, whereas the EES and EC are closely related to the engineering portion. The advanced e-manufacturing model takes advantage of the information and internet technologies to efficiently integrate the MES and EES within a company (intercompany integration) and the SC and EC among member companies (intercompany integration). From what is discussed by Cheng et al [11], by using this model the productivity and yield of a complete production platform can be improved by MES. The overall equipment effectiveness (OEE) can be enhanced by EES. The order-to-delivery (O2D) period can be reduced by SC, and the time to market (T2M) can be shortened by EC.

3. ASIAN TIGERS

Economies of Hong Kong, Singapore, South Korea and Taiwan after 1970 are referred to as Asian Tigers. According to Thomas White [66], South Korea and Taiwan have transformed themselves from being the manufacturing backyards of the U.S. and Japan into high-tech giants in just over a generation. Researchers like Hernandez [22], Ouyang [54], Hobday [23], Hu [27] and Chew [12] have written about the industrial policies implemented in Taiwan and South Korea which created a platform for the implementation of e-manufacturing in the two nations

According to Mathews et al [42], Korea's success came through the establishment of industrial conglomerates (chaebol). In contrast, Taiwan depends on a multiple of small and medium sized firms. Their economic success stories which became to be known as the Miracle on the Han River and the Taiwan Miracle respectively can serve as models for many so-called developing countries according to Wikipedia [72]. With the emphases being put on the development of the SMEs in South Africa so as to create employment, the Taiwanese model of growth is more applicable in the South Africa.

3.1 Taiwan Case Study

Taiwan successfully established a stable socio-economic and political system, characterized by impressive growth rates and equitable income distribution which many developing countries in Africa and Latin America have been trying to do since independence (White [70]). The success of Taiwan's economy came mainly from its semiconductor industry.

Many researchers have written about success of the semiconductor industry development in Taiwan. Mathews [43] uses a four-phase development model to explain the role and importance of local government and public research institutes in the Taiwan. Chang et al [7], Tung [65] and Aoyama [3] use five stages based on the perspective of the acquisition and enhancement of industrial technological capabilities. Chang et al [8] examines the interactions between the government, research institute and the domestic industry. White [70] describes the development of the industry in different periods which helped develop Taiwan's competitive advantage and thus stimulated foreign direct investment. Cheng et al [10] use the system dynamics model to come up with three stages which involved interactions between government and industry on the first stage, interaction between industry and the domestic socioeconomic environment in the second stage and industry firms rapidly expanding through interaction with the international environment in the third. It can be seen from the statements above that the Taiwanese government and research institutions played a major role in the development of the semiconductor industry.

As discussed earlier, the success of the Taiwanese industry was due to its ability to cut down production cycle times and costs by implementing e-manufacturing. The factors that lead to the successful implementation of e-manufacturing in Taiwan can be summarized as:

1) Government initiatives (Liu [39], Chang [8]),
2) Research and development (Tung [65]),
3) Creation of a knowledge innovation (NSTDP, [51]) and

4) Taiwanese entrepreneurship culture in SMEs and networks in the industrial clusters (Hu et al, [28]).

3.1.1 Government initiatives

Researches like Chen [10], Ouyang [54] and Mathews et al [42] have shown that the Taiwanese government developed polices that natured and promoted the semiconductor industry. It created Public Research Institutes (PRIs) like Industrial Technology Research Institute (ITRI), public sector infrastructure like the Hsinchu and Tainan industry parks and science-oriented universities like National Chiao Tung University (NCTU) and National Tsing Hua University (NTHU). It made the electronics industry particularly the semiconductor industry and technology upgrade a top priority. ITRI sent its staff to technological conferences and trade shows, and brought back the latest technologies to Taiwan. The first two IC companies in Taiwan UMC and TSMC came from IRTI. When local private investors were not willing to participate in the formation of TSMC the Ministry of Economic Affairs (MoEA) had to use threats of tax auditing, stopping issuing permits, government contracts and loans to get needed private sector involved (Ouyang [54]).

The Executive Yuan announced the “National Development Plan” which was meant to serve as guiding principles for the government to follow in boosting national competitiveness and transfiguring Taiwan into a “Green Silicon Island”. In the plan the government proposed the e-Taiwan construction plan and sought to bring broadband to six million households, promote e-society, e-commerce, e-government and e-traffic. In the National Science and Technology Development Plan (2005 to 2008) the emphasis was on the e-Taiwan, e-life vision which helped networking people. This helped in increasing collaboration of SMEs in industrial clusters as they used internet to communicate and share information (Wei [69]).

3.1.2 Research and Development

The Taiwanese government introduced foreign technology through research institutes and ever since then it has been making reviews in its National Science and Technology Conferences and National Science Council Executive Yuan meetings (Chang, [7]). It has continued to invest in research and development as shown by Hsieh [24], Mathews [41], Tai et al [61] and Hsu et al [26]. Figure 7 shows that there has been a gradual increase in the total expenditure in research and development in Taiwan. The business enterprise sector is now the major investor in research and development as opposed to the early 80s when it was the government. Hsu et al [26] discusses how R & D contributed to innovation in the semiconductor industry in Taiwan.

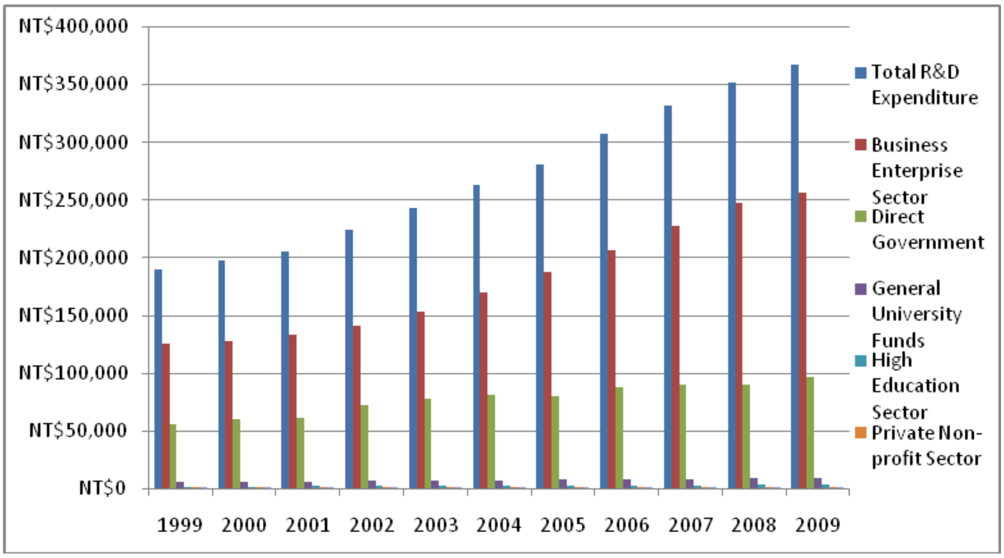

Figure 7: Taiwan annual R&D Expenditure (Source NSC [50])

According to Saha et al [57], one of the enablers of e-manufacturing is introduction of Advanced Manufacturing Technology (ATM) hence Taiwan's research and development is manly concentrated on Engineering and Technology category as shown in Figure 8. Due to the complicated design process and enormous design cost in semiconductor design, in a bid to cope with design collaboration in the industry ITRS proposed the concept of Engineering Chain (EC) (Chang et al [7]). This was to facilitate more data to be exchanged among the heterogeneous companies to assure a successful IC design cycle in fast speed.

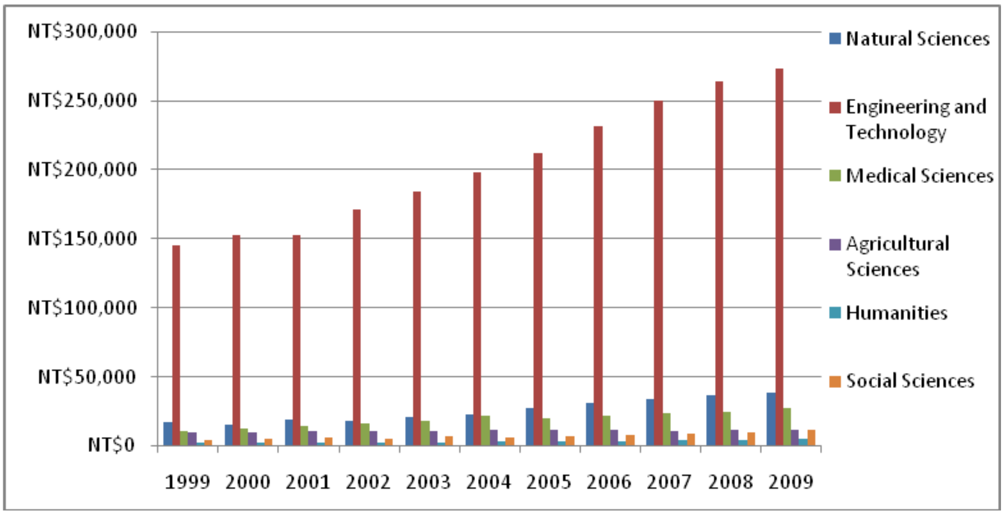

Figure 8: Areas of R & D (Source NSC [50])

Though Taiwan had set a goal in its "Challenge 2008 National Development Plan" to increase R&D expenditures to 3% of GDP by the year 2006, it had almost reached the figure by 2009 as shown in Figure 9. According to OECD [52], Taiwanese expenditure is higher than most of the OECD nations shown by its April 2011 data. This will help to keep Taiwan ahead of other countries in semiconductor manufacturing.

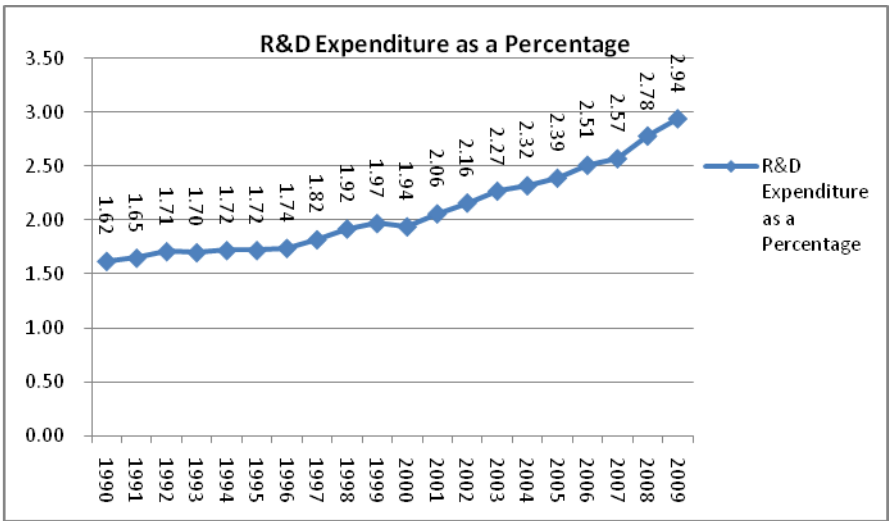

Figure 9: R & D Expenditure as a percentage of GDP (Source NSC [50])

3.1.3 Creation of a knowledge innovation

In its Visions and Strategies for the Development of Science and Technology (2003 – 2006) plan Taiwan proposed the following targets:

i) *Increase the number of researchers with university degrees or above to 32 person-years (full-time equivalent) per 10,000 population by the year 2007.*
ii) Have *at least one university rising to world-class standards by the year 2013.*
iii) *Have at least 3.5% of all granted US patents (not including new design patents) will go to applicants from Taiwan by 2007*
iv) Industrial technology environment will be created to offer international advantages in the manufacturing and service sectors
v) Develop Science parks will, and integrate regional R&D resources to form regional industry clusters.

According to Lin [38] and Ko [31], it is the experience in manufacturing and the well-educated working population (shown in Figure 10) which promoted policies favouring the growth of high-tech industries. Taiwan managed to link R&D in its research institutions and its industry which has helped the growth of the industry.

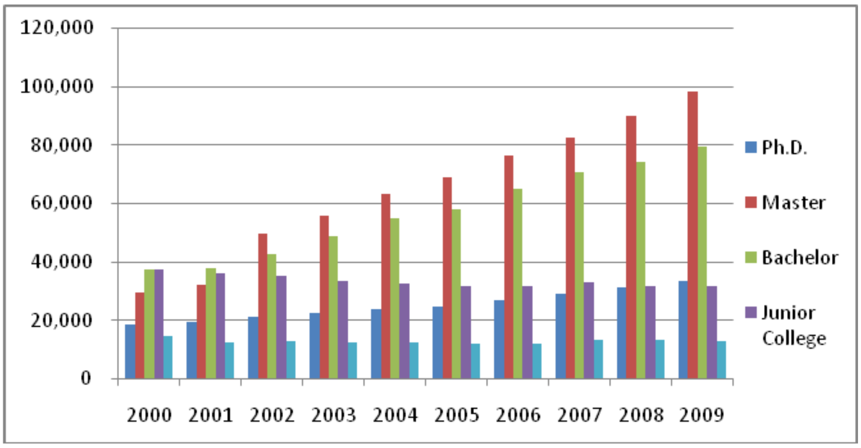

Figure 10: Number of degree personnel (Source NSC [50])

3.1.4 Taiwanese SMEs and industrial clusters

The first Taiwanese incubator centre was set up by Industrial Technology Research Institute (ITRI) with the assistance from Small and Medium Enterprise Agency (SMEA) in 1996 as one of the moves under the macro policy of "Asia Pacific Operation Center". Since then, incubators all have been set all over Taiwan and most of them are located within the university campus (Wu [73], Jones et al [30]). SMEA has paid more and more attention to encouraging innovation in the incubators. SMEs constituted about 97.9% of businesses during the period 2000 and 2004 (Ko [31]) and can enjoy equally or even higher competitive advantage than their larger competitors by appropriately utilizing external networks (Narula [48], Hagedoom [21]). Industrial clusters in Taiwan were formed to take advantage of the competitive advantage, entrepreneurial spirit and dynamism spirit in Taiwan and advantages explained by Allen et al [1], Bohman et al [6] and Chell et al [9]. According to Hu et al [28] SMEs overcame their competitors by joint R&D service outsourcing. Tai et al [61] explains how collaborative innovation networks between these SMEs enhanced their innovativeness. Kuchiki et al [34] state that cluster formation is a key for such a rapid development and this seems to be what worked for Taiwan.

The implementation of industrial clusters helped to build networks in the semiconductor supply chain and set up a platform for the implementation of e-manufacturing. Starting with foundries, Taiwan has built a semiconductor supply chain complete with IC design, wafer fabrication and IC packaging and testing (Chang [8]). The country was ranked No. 1 in the world in IC manufacturing, packaging and testing, and No. 2 in IC design in terms of global market share in 2009 with an output of NT$1.229 trillion (US$39 billion) in the semiconductor sector.

3.1.5 Results of e-manufacturing implementation - Taiwan Semiconductor fabrication capacity

Taiwan managed to implement a successful e-manufacturing model which saw its semiconductor industries growing from one of the smallest to be one of the largest in the world. Foundry fabrication capacity in Taiwan began to experience rapid growth in the period 1995 – 1999 when the supply chain was formulated and virtual integration took shape in the supply chain (Tung [65], Leachman [36]). E-manufacturing has enabled more collaboration in the supply chain.

China Post reports that Taiwan Semiconductor Manufacturing Co (TSMC) and United Microelectronics Corp (UMC) are the largest and second largest made-to-order chipmakers in the world respectively, as well as famous IC design houses, DRAM chipmakers and IC testing and packaging firms (Chinapost [13] , [14]). Figure 11 shows that Taiwanese foundries were at top of the world's top 17 semiconductor foundries in 2009.

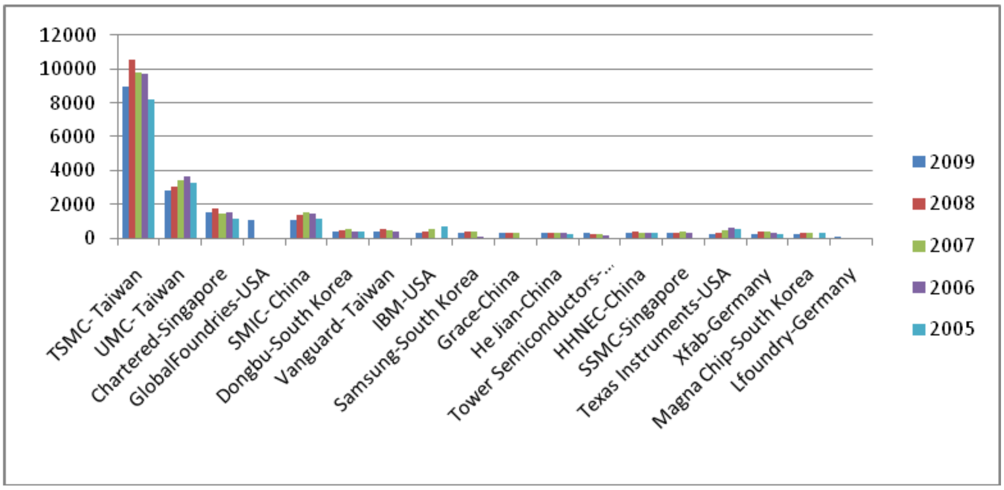

Figure 11: Revenue (million $USD) of top 17 semiconductor foundries in 2009 (Source Wikipedia [71])

Foundries contribute the most revenue in Taiwan semiconductor industry as shown in Figure 12. The growth of the Taiwanese semiconductor industry can also be seen in the industrial indices. Figure 13 shows revenue of Taiwan IC Fabless Business. The effects of the global financial crisis can also be seen in the decline in industrial indices in 2008.

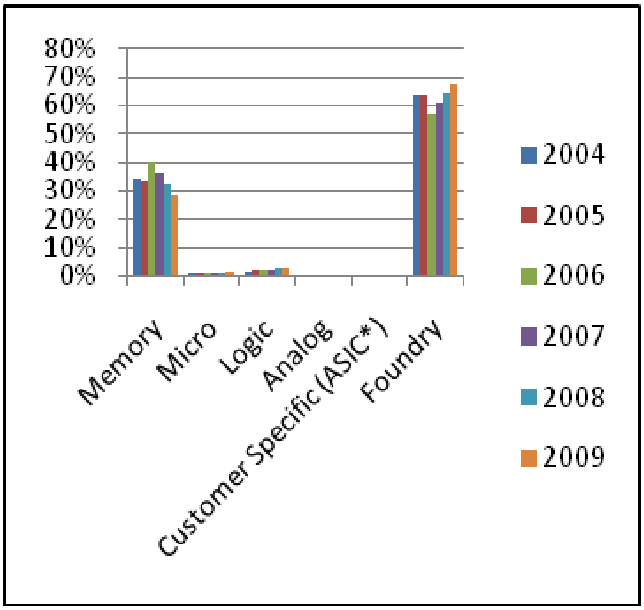

Figure 12: Business Sectors of IC Fabrication in Taiwan (Source TSIA, [63])

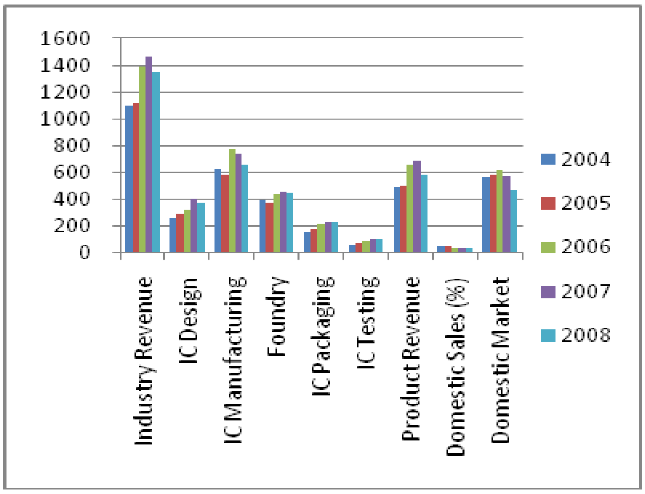

Figure 13 Revenue (NT$B) for Taiwan IC Industry (Source TSIA, [64])

The Taiwanese model shows that collaboration in companies is crucial for the growth of the economy. SMEs have flexibility which enables changes in products to be implemented faster and at lower costs. Industrial clusters enable them to utilize economies of scale to lower unit costs. South Africa has a lot to learn from Taiwan's e-manufacturing model and success. We now turn our focus on the current situation in South Africa and examine how prepared is South Africa to implement e-manufacturing.

4. SOUTH AFRICAN SITUATION

The South African economy is a mixture of large corporations and SMEs. Using the example of Taiwan, South Africa can benefit from the collaboration of SMEs and the large corporations in keeping the flexibility required in product changes and reducing products costs. Most of the companies have ERP systems like SAP which enhances the supply chain of the e-manufacturing model. Comparing the situation in most of the industries in South Africa the automobile industry is best suited to implement e-manufacturing. The automobile industry has managed to strengthen collaboration between companies in clusters and original equipment manufacturers (OEMs). The OEMs have taken the lead in adopting innovative applications of network-based IT and this creates a platform for the implementation of the model. The order to delivery period in the supply chain can be reduced by taking advantage of the internet. The time to market on products from component manufactures can be reduced by taking advantage of collaborations in the engineering chain.

We will look at the how South Africa is prepared to implement e-manufacturing in the four areas that enabled Taiwan to implement its model i.e.

1) Government policies.
2) Research and development.
3) Creation of a knowledge innovation.
4) SMEs and industrial clusters.

4.1 Government Policies

Just like the Taiwanese government the South African government developed an e-government policy as part of its overall service delivery improvement programme in 2001 with main emphasis on e-government (Government to government or G2G), e-service (Government to Citizens or G2C) and e-business (Government to Business G2B e.g. procurement). This is a positive development in creating a platform for e-manufacturing but the government has faced challenges, such as providing education and training on the usage of the electronic model, addressing the lack of preparedness by government institutions, consumers, companies, SMME's and managing the negative socio-economic impacts, for example, job losses and other associated risks (Naidoo et al [47]).

In its 2010/11 – 2012/13 Industrial Policy Action Plan the government of South Africa identified that there are opportunities in extending value chains through further downstream manufacturing metals component manufacturing in the new Automotive Production and Development Programme. It also noted that its major constraints were in the ad hoc procurement and unrealistically short delivery times often demanded by State Owned Enterprises (SOEs) and government departments and lack of competitive financing of South Africa companies especially lower tier suppliers. To address these problems it set the following key action programmes:

i) Identification of fleet programmes/products to make investments in associated supply chains viable and thereby promote local manufacturing.
ii) Competitive Financing Programme for suppliers into public CAPEX programmes.
iii) Benchmarking and matchmaking programme.
iv) National Tooling Initiative (NTI).
v) National Foundry Technology Network.
vi) Facilitate the upgrading of the White Goods industry to increase production and grow exports.

The policies implemented by the South African government are almost similar to those implemented in Taiwan. If fully implemented the policies lay a good platform for the implementation of e-manufacturing as they will enable collaboration in the supply chain. The problem South Africa has had with other proposed initiatives proposed has been that policies are drafted but the stakeholders do not put action in implementing them (Timm [62], Naidoo [47]). E-manufacturing can assist to meet the short delivery times demanded by the SOEs and government departments. Benchmarking and matchmaking will close the information gap between SOE demand and supply capabilities which is the focus of e-manufacturing. On the other hand connectivity offered by e-manufacturing will also help in benchmarking and matchmaking.

4.2 Research and development

South Africa's research and development (R&D) expenditure grew fivefold from about R4 billion in 1997/98 to about R21 billion in 2008/09 (HSRC [24]). According to South African National R&D Surveys and Statistics, there was a steady increase in South Africa's gross national expenditure on R&D (GERD) expressed as a percentage of GDP between 2001 and 2006, which rose from 0.73% to 0.95% of GDP as shown in Figure 14 (SANRDSS [58]). The gross national expenditure on R & D in South Africa in 2008 was still less than that of Taiwan in 1987 and the OECD target of 3% as shown in Figure 15.

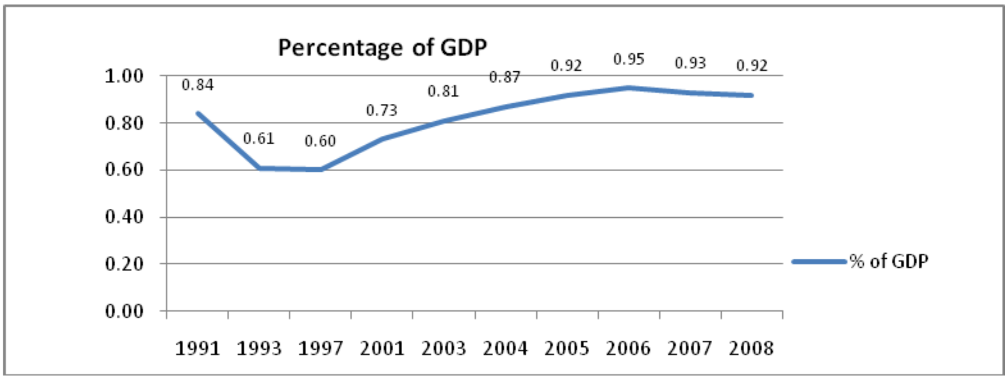

Figure 14: Gross national expenditure on R&D as a percentage of GDP (Source HSRC [24])

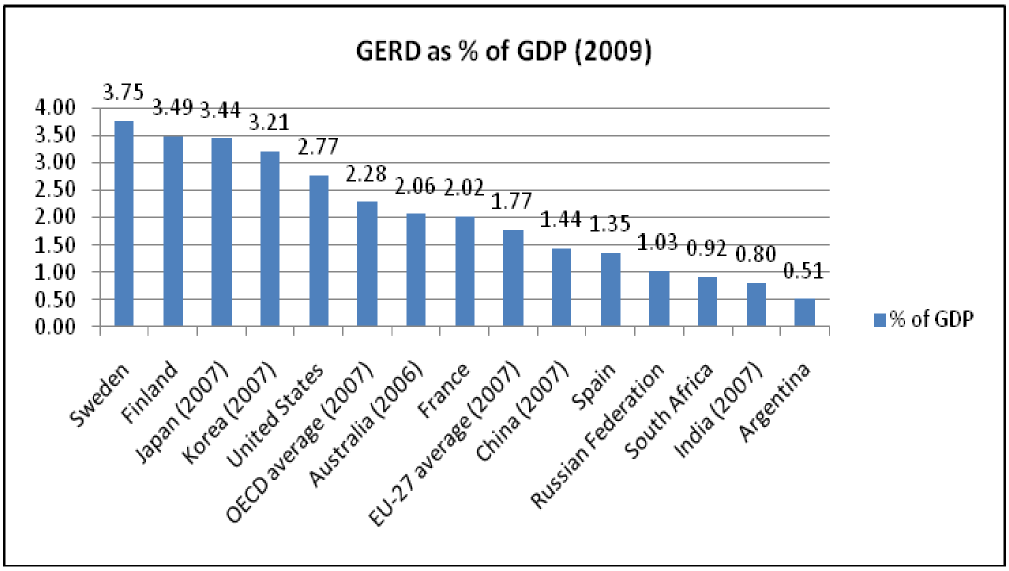

Figure 15: GERD as a percentage of GDP for OECD countries (Source OECD [52])

According to the Department of Science and Technology South Africa's 2010 report few OECD countries have a GERD equivalent to less than 1.0% of GDP. In order for South Africa to catch up with these nations and also to have a successful e-manufacturing model investment in R & D should be increased. E-manufacturing will companies to be linked to the research institutions. R & D departments in the companies will be linked to the factory floor for faster implementation of the results of R & D.

Most of the research in South Africa is in Engineering Sciences and Natural Sciences as shown in Figure 16. This enhances the developing industry in South Africa.

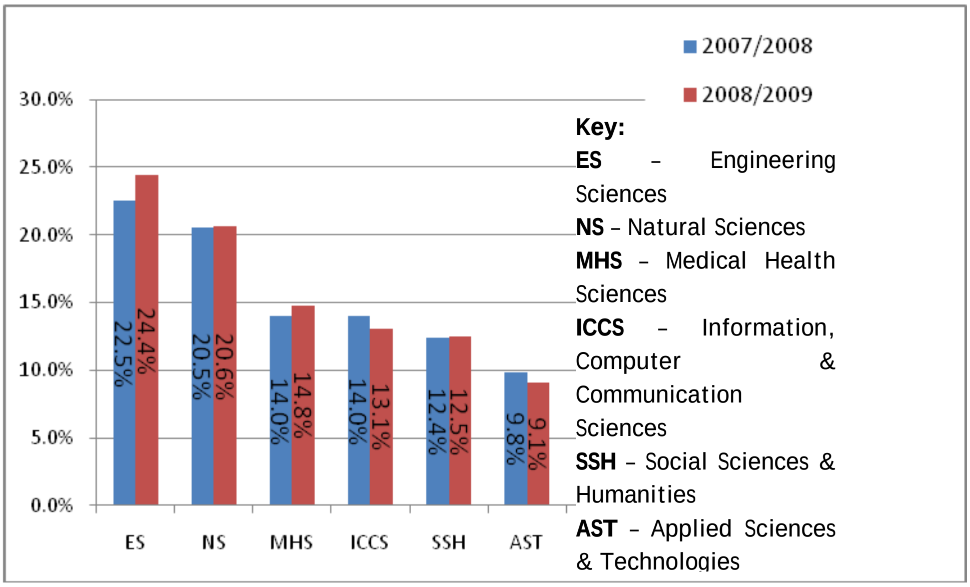

Figure 16: Percentage expenditure on R&D by major research field (Source SANRED [58])

4.3 Creation of a knowledge innovation

According to the Department of Science and Technology [16] and [17], South Africa adopted a Ten Year Innovation Plan (2008-2018) in July 2007 whose major emphasis is the commitment to *national action for transitioning to a knowledge based economy* through:

- Human capital development (HCD).
- Knowledge generation and exploitation (R&D).
- Knowledge infrastructure development.
- Addressing the "innovation chasm" between research results and societal benefits.

The focus of the South African government is to have economic growth led by the production and dissemination of knowledge for the enrichment of all fields of human endeavor. This is a step towards South Africa's innovation revolution. With e-manufacturing in place innovation can be speeded up as companies increase collaboration.

Comparing the number of graduates in South Africa and Taiwan, South Africa is doing well in the undergraduate category. Figure 17 shows the number of graduates in South Africa. It is still behind at masters and doctorate levels hence it has to increase enrolment at masters and PhD level. According to the Department of Science and Technology, for South Africa to build a knowledge-based economy positioned between developed and developing countries, it will have to increase its PhD production rate by a factor of about five over the next 10-20 years.

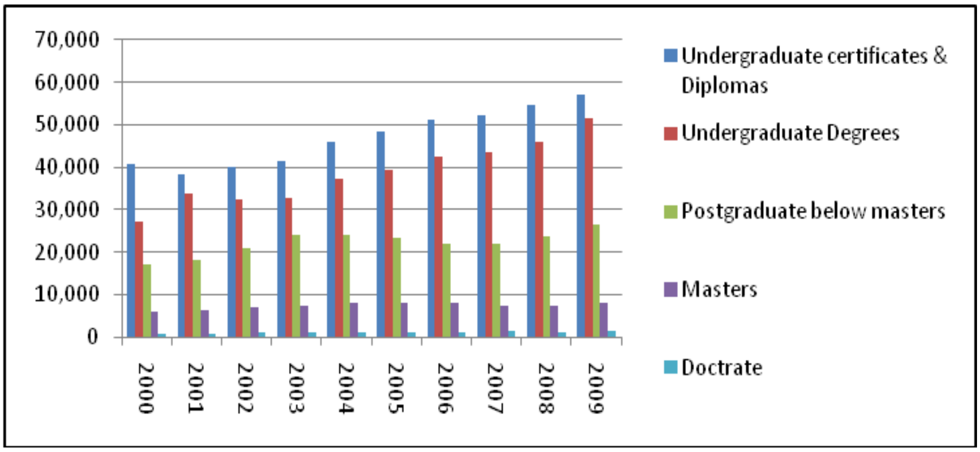

Figure 17: Number of graduates in South Africa (Source DOE [15])

4.4 SMEs in South Africa

SMEs have played a major role in job creation in South Africa. According to Finscope between 1985 and 2005, 90% of all new jobs were created by small, micro and medium firms (Statistics South Africa [60]). The Department of Trade and Industry's Annual Review of Small Business 2006-2008 states that South Africa had 2.43 million small enterprises in 2007. Small and micro enterprises contribute between 27% and 34% of South Africa's GDP (Timm [62]). Although SMEs have this contribution to South African economy, their failure rate in is one of the highest in the world as about 75% of new SMEs in South Africa do not become established firms (Olawale et al [53]). Some of the factors contributing to the failure of SMEs noted by Olawale et al [53]) are lack of networking, investment in information technology and high cost of production. Lack of networking and sharing of information has had a negative impact in the development of SMEs as some do not benefit from government programs because of lack of knowledge. Though the South African government provides support to SMEs, only 13.5% of entrepreneurs have heard of Seda and 1.3% had accessed the agency in the Gauteng Province. In the Western Cape just 10% are aware of Seda, and 0.5% has visited a Seda branch there. Only 3% of entrepreneurs reported that they had heard of Khula, while 10% said they had heard of National Youth Development Agency (NYDA) and 4% said they had heard of Seda. Only one percent of small businesses reported that they had visited Seda or NYDA branches (Timm [62]).

From the list of statements above, for the e-manufacturing model to succeed in South Africa collaboration among the SMEs should be increased. Linking SMEs over the internet will help to increase networking between the SMEs. The government will have to step up awareness campaigns the programmes it has which supports the SMEs and the SMEs should also be willing to share information.

4.5 South Africa's industrial clusters

Industrial clusters are fairly new in South African industry but almost as old as Taiwan's industrial incubators and in most of the cases not yet well established. The Department of Trade and Industry invested heavily in studies on how to support clusters from various sectors in the 1990s. It set up the Sector Partnership Fund, Workplace Challenge Programme and Competitiveness Fund to boost intra-firm and inter-firm co-operation which. It then worked to popularize the cluster approach through workshops with key sectors in main manufacturing regions, through Spatial Development Initiative projects. These efforts did not always translate to sustained collective action by the stakeholders concerned as they felt that the government did not have a clear funding programme to use to back up the formation of clusters (Timm [62]).

In most of the cases these efforts resulted in one-off projects rather than in sustained networking. Where networking did take place this failed to go beyond single-issue processes, such as the Port Elizabeth auto cluster where the sole focus was on logistics (Timm [62]). Clusters seem to be getting more established in the automotive industry. Lorentzen [40] discusses how the Durban Automotive Cluster (DAC) lowers the costs of information provision about markets, product standards, process requirements, and other variables that determine the competence with which firms confront global value chains

Lack of the establishment of clusters in South Africa is a major setback to the establishment of e-manufacturing in South Africa. According to Morris et al [46] and Timm [62] South Africa's short experience has yielded some key lessons for the country's policymakers, namely:

- There is no clear funding from government.
- Clusters need to retain sector-specific staff.
- Government must not set overt political agenda.

For an e-manufacturing model to be successful in South Africa the above factors have to be addressed as clustering plays an important role in e-manufacturing especially in the Supply Chain and Engineering Chain. Collaboration between companies in the clusters should be encouraged and increased.

5. BENEFITS E-MANUFACTURING CAN BRING TO SOUTH AFRICAN INDUSTRY

A survey done on companies that have implemented e-manufacturing strategy shows that they have managed to perform better than those using MPRII, lean manufacturing and six sigma strategies as shown in Table 1.

	Average Plants Classic MRPII Manufacturing	Best Plants Enterprise and Six Sigma	E-Manufacturing Plants
Lead Time	3 months	3 days	12-24 hrs
Quality Level (Defects)	500 ppm	50 ppm	3 ppm
Inventory Turns	5 x per year	10 x per year	20 x per year
Delivery Performance	90%	98%	99.9%
Sales Growth	3%	8%	10%
RoS%	10%	16%	20%

Table 1: Potential benefits of implementing e-manufacturing (Source Greeff et al [19])

Some of the typical benefits companies in South Africa can get from implementing e-manufacturing strategy are (SoftwareToolbox [59]):

- Inventory Reduction 25%-60%
- Cycle Time Reduction 30%-45%
- Delivery Performance 16%-28%
- Forecast Accuracy 25%-80%
- WIP Reduction 17%-55%
- Data Entry Time Reduction 50%-75%
- Paperwork Reduction 35%-55%

- Defect Reduction 15%-35%
- New Product Introduction Time 30%-65%

6. WHAT SOUTH AFRICA HAS TO DO

From the list of statements focusing on the situation about South Africa, the main areas lacking in order to implement a successful e-manufacturing strategy in South Africa are:

1) The government has drafted policies that create a favorable platform for the implementation of the e-manufacturing strategy in companies. In order for e-manufacturing to be successful the government should put action in implementing its e-government policy and policies documented in the 2010/11 – 2012/13 Industrial Policy Action Plan.
2) Though there has been a gradual increase in R & D expenditure, investment in R&D needs to be increased as is reflected by the fact that the gross national expenditure on R&D as a percentage of GDP for South Africa in 2008 was still less than that of Taiwan in 1987. Collaboration between research institutes, universities, government and industry also should be increased.
3) The number of researchers (masters and doctorate students) is still far much lower than Taiwan and needs to be increased.
4) There is still less collaboration in business people. A platform to share information between SMEs and companies in industrial clusters has to be created. This would result in bridging the gap between companies and SMEs, take advantage of the flexibility that SMEs have and the production capacity of large companies to cope up with product changes and reducing production costs. Collaboration in industrial clusters helps to build the supply chain and engineering chain of the e-manufacturing model.
5) Lack of funding, skilled manpower and government infiltration has hindered the success of industrial clusters hence needs to be addressed.

7. CONCLUSION

The Taiwanese model of economic growth shows how an economy can experience rapid economic growth by utilizing supply chain and engineering chain of clustered small to medium sized firms. The e-manufacturing model in Taiwan benefited from government policies, research and development, creation of a knowledge innovation and collaboration in industrial clusters. South Africa can learn from the Taiwanese e-manufacturing model as it has almost the same background of an economy boosted by the SMEs like Taiwan. The government of South Africa has implemented policies that favor the establishment of e-manufacturing and transitioning to knowledge based economy. Though investment in research and development is still lower than most of the developed countries, South Africa is not very far from catching up with them if the Ten Year Innovation Plan (2008-2018) is fully implemented as it focuses on the Knowledge generation and exploitation (R&D). The major setback in South Africa is in the development of industrial clusters and collaboration in industry. Success of industrial clusters has been muted by lack of government funding and a policy which would make the clusters operate without government trying to pursue political agenda. Business people should collaborate if a successful e-manufacturing model has to be implemented in South Africa.

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