

ACCESSING THE GLOBAL ENGINEERING MARKET THROUGH DIVERSIFICATION OF THE GHANAIAN TEXTILE INDUSTRY

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In the mid-1970s, Ghana enjoyed a boom in the textile industry, but the lack of diversification has driven this once vibrant sector towards imminent collapse. This paper conducts a review and suggests a model that can alter the textile industry's fortunes by simultaneously introducing, composite fabrics alongside normal cotton and bamboo fibre fabrics. Composite textile manufacturing has the potential of opening access to the following global industries, namely; wind power, aviation, automotive, boat making, sports and piping. As the world gravitates towards greener, energy efficient and recyclable products, industries are gradually turning to textile composites like Non-crimp Fabrics. These fabrics tend to have lower raw material cost, weight and longer life cycles when compared with traditional materials such as Aluminium. The research revealed that Ghana already has the textile manufacturing infrastructure which may require some modifications and personnel training and therefore the Ghanaian textile companies can strive to place themselves in the supply chain systems of the aforementioned industries. The government must also play its part by providing the economic incentives for such a radical venture to survive by adopting the South African approach. South Africa is the only African country that finds itself in the global supply chain market for composite textile. This success is due to the strategic introduction and implementation of policies such as the Automotive Production Development Programme (APDP) and reduction in tariffs on light vehicles and components which are key features that has allowed companies such as Saertex South Africa to thrive in the production of composite textiles.

Keywords: Composites, Infrastructure, Non-crimp fabrics, Supply chain, Resin Transfer Moulding, Resin film Infusion.

1 INTRODUCTION

The Ghanaian textile industry is suffocating under immense pressures from tough external competition from cheap Chinese imports, lack of innovation, diversification and national policy direction Olarewaju (2001). The industry during its peak in the 1970s could boast of 16 textile companies, 138 garment-manufacturing firms and employed about 25000 people. The dwindling fortunes of the industry has shrunk the employee numbers to 2961 and only four (4) out of the 16 textile manufacturing companies have managed to survive the turbulence, they are namely; Akosombo Textile Limited (ATL), Ghana Textile Manufacturing Company (GTMC), Ghana Textile Product (GTP), and Printex. Although GTP leads in the Ghanaian market, it however produces at only 30% capacity while Akosombo Textile Limited (ATL) is the only company that has not shut down its spinning and weaving department(Bruce-Amartey *et al.*, 2014; Quartey, 2010; Quartey, 2006).

With the current state of the industry, predicting its total collapse within a few years is plausible and therefore drastic and innovative approaches are required to turn its fortunes around. The south African automotive industry approach of governmental policies, strategic planning and funding has yielded results worth emulating. This paper seeks to offer a unique paradigm shift from sole concentration on normal

fabrics to Non-crimp fabrics which can open access to major engineering industries such as the automotive, aerospace and wind turbine industries. Fortunately Ghana has the all the raw materials and infrastructure for manufacturing NCFs.

2 COMPOSITE MATERIALS

The history of man-made composites can be traced to thousands of years ago and the use Wattle-and-daub, one of the oldest man-made composites, dates 6000 years Shaffer (1993). The term composite is derived from the Latin word *compositus*, which stems from the root word *componere* and literally means “to bring or put together”. There are several scientific definitions provided by several researchers. Tsai (1965) defined composite materials as “consisting of two or more constituent materials bonded together so that the gross properties of the composite are superior to those of the constituents” while Agarwal (1990)describes a composite material as “a material that has two or more distinct phases or constituents.”

3 NON-CRIMP FABRIC COMPOSITES

Non-crimp fabric composites can be defined as “a textile structure constructed out of one or more laid parallel non-crimped non-woven thread plies, which are differently oriented, with different thread densities of single thread plies and in which integration of fibre fleeces, films, foams, or other materials is possible” Phillips (2009). The foundation for non-crimp fabric composites manufacture was established in 1949 by Heinrich Mauersberger with patent number DD00000008194A. The manufacturing process involved using chain-stitch seams to interlink loose filling threads or drawn parallel wet threads Mauersberger, (1954). However, the first Non-crimp fabric composites (NCF) was manufactured in 1983 with a +45° and -45° ply configuration knitted together Steggal (1999). The main driving factor for the switch from Unidirectional Pre-impregnated tapes (UDPT) /autoclave to NCF/resin infusion is the economic gains derived. Bibo *et al.* (1997) confirmed the above assertion by observing a cost reduction of 35% as labour cost for UDPT. The labour cost which included debulking and laying down of material, constituted 50% of the final cost while the material cost was 25%. Figure 1 is a schematic of a multiaxial Non-crimp fabric. Textile production equipment were adapted successfully for the manufacture of NCF using glass, carbon aramid and in some cases ceramics fibres. The textile industry’s highly automated and cost effective manufacturing processes such as stitching, weaving, braiding and knitting greatly benefits the manufacturing of the dry NCFs Mattsson (2005). The manufacturing process of non-crimp fabrics can be summarized under two major steps; namely manufacture of preforms and moulding of preforms.

3.1 Manufacture of Preforms

Preform manufacture involves binding optimally placed stacked tows of non-crimp fibre together by warp-knitting as illustrated in figure 1.

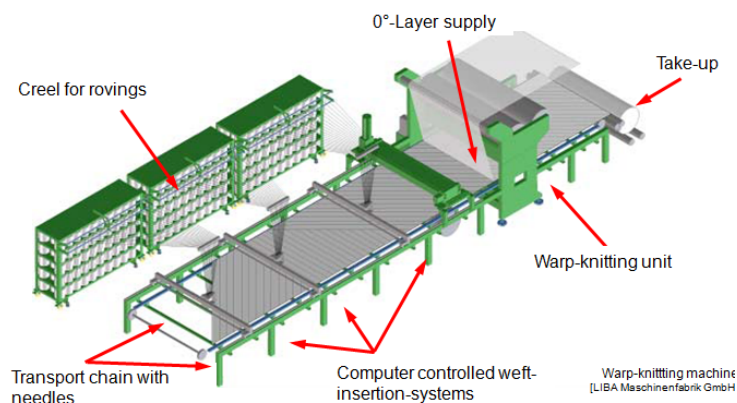


Figure 1. Warp-Knitting machine (diagram by Liba), source: Mattsson (2005)

Typical stitching yarns include polyester or aramid (Bibo *et al.*,1997; Dexter and Hasko, 1996; Hogg, 1993). Bi, tri and quadriaxial fabrics can be produced using this production technique as shown in figure 2 . The dry preforms can be stacked to obtain required thickness then cut to the desired shape before moulding.

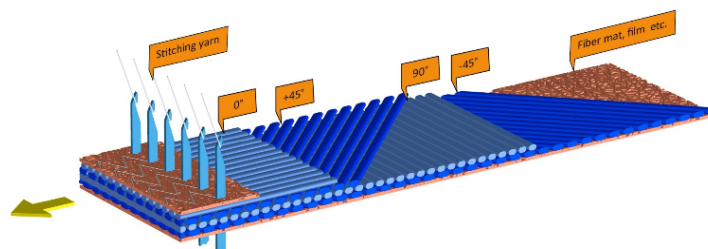


Figure 2. Stitching of Multiaxial NCF, source: Seuß (2014)

3.2 Moulding of Preform

The moulding techniques used are classified as Liquid Composite Moulding (LCM) methods. There are several methods available but they all basically require injection of a liquid monomer (a low viscosity resin) into a cavity containing a preform [Hogg, 2005]. The two main moulding methods are Resin Transfer Moulding (RTM) and Resin Film Infusion (RFI).

3.2.1 Resin Transfer Moulding (RTM)

Mazumdar (2002) described the basic steps of RTM as; Step 1: Place catalyst and thermoset resin in separate tanks of a dispensing apparatus. Step 2: Apply a release agent to the form tool. Step 3: Place preform into the mould and secure mould with clamps. Step 4: Apply heating to mould. Step 5: Inject the mixed resin through inlet ports at a pre-determined temperature and pressure (a vacuum is created in the case of Vacuum assisted RTM (VARTM)). Step 6: step 5 continues until the mould is filled, then the Vacuum is turned off and the outlet port is closed. Step 7: remove part after it cures. Figure 3 illustrates the RTM process.

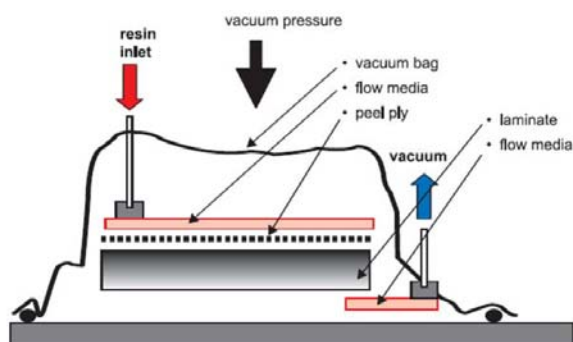


Figure 3. Cross-section of VARTM Tool by Philips, (2009)

3.2.2 Resin Film Infusion (RFI)

This process is based on a resin film concept where a pre-calculated resin film is spread onto the tool surface while the dry preform is placed on top. To cause the resin to infiltrate the entire thickness of preform, heat and pressure are finally applied as depicted in figure 4.

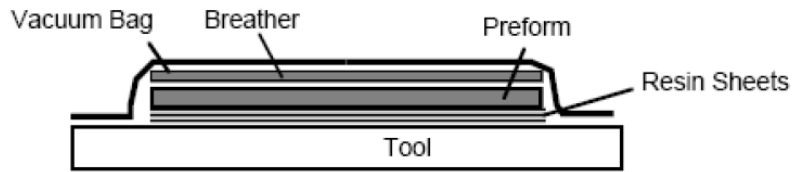


Figure 4. The RFI Process (schematic by Philips, (2005))

The main advantage of RFI is that only one tool surface is needed and, therefore, part size has no economic or technical restrictions as the resin flows through the thickness Philips, (2005).

RTM and RFI are preferred because of low material waste, reduced production time and ultimately lower manufacturing cost as a result of the unlimited shelf life of composite produced Leong (2000).

3.3 Non-Crimp Fabric Composites in the Aviation Industry

Composites have a long history in aircraft design, notable amongst them are the British Spitfire (World War II) which incorporated hemp fibre and phenolic resins, the use of glass fibre/honey comb-core sandwich since 1950, the application of boron/epoxy composites in 1960 and the introduction of carbon/epoxy and Kevlar/epoxy in the 1970s Gay *et al.* (2007). Decreasing an aircraft's weight is directly linked to improving its efficiency and performance and therefore composites are best suited for aeronautic applications because of their capabilities for integral design, better weight-specific stiffness and strength at an acceptable cost. The main competition is Aluminium, Steel and Titanium alloys Kalanchiam and Chinnasamy (2012). In recent times, the percentage of composite use in the two leading commercial aeroplane manufacturers, namely Airbus and Boeing has steadily risen. The importance of weight saving, to reduce fuel consumption and meet stringent environmental law will make the use of composites, even more, important in the near future.

The Airbus A340 (1990-2000) consisted of 17% composite structures while the A380 (2000-2010) saw composite structure increase of 25% as illustrated in figure 5a. However, the A350 XWB (which is upcoming) consists of 50% composite structures. Carbon fibre reinforced polymer (CFRP), is the main composite material used for the majority of parts manufactured with prepreg as the base material. The few parts produced using resin infusion technology are mostly non-crimp fabrics (NCF) composites. For example, the Airbus A380 rear pressure bulkhead was developed completely from carbon NCF and is one of the biggest aeronautic NCF parts Middendorf and Metzger, (2011). The Boeing 787 was also designed with 50% composite structure as shown in figure 5b.

Composites such as NCFs will become the material of choice due to continuous rise in oil price and changing attitude to environmental issues from bodies such as the Advisory Council for Aviation Research and Innovation in Europe ACARE (2015), which is targeting 50% reduction in Co₂, 50% reduction in noise levels and reduction in NO_x by 2020.

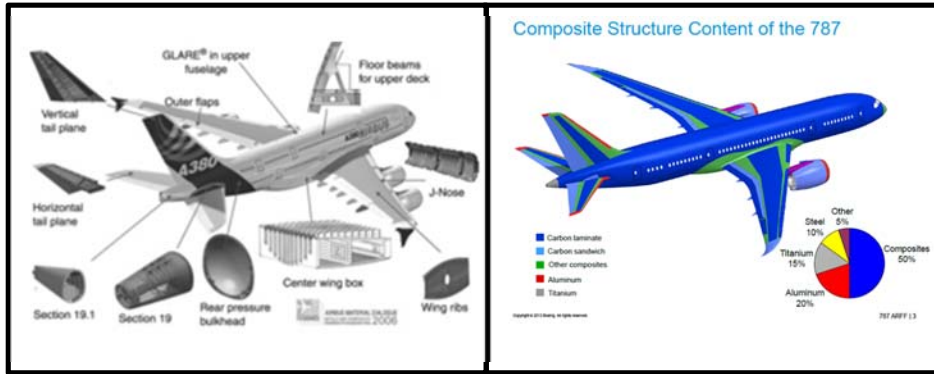


Figure 5a

Figure 5b

Composite application in the manufacture of Airbus A380(Figure 5a) and Boeing 787 (Figure 5b) (Airbus, 2006; Boeing, 2013)

3.4 Non-Crimp Fabric Composites in The Automotive Industry

3.4.1 Global Trend

The Global production of vehicles is dominated by eleven Original Equipment Manufacturers (OEMs) with origins from the US, Europe and Japan with Toyota continuing its dominance of the market share ahead of GM and VW. These OEMs mainly concentrate on the combination of efficient improvements, increased productivity and relocating closer to current and emerging markets as tools to reduce cost. In 2014 vehicle production rose by 2.6% (87,51 million (2013) to 89,75 million units) and also an increase in sales of 3.1% (85,47 million to 88,16 million vehicles) AIEC (2014).

China has seen an increase of 3% to 22% in the world production share from 1997 to 2009 and outsold and produced more vehicles than both the US and Japan put together in 2014 (Bailey *et al.*, 2010; AIEC, 2014). The BRICS group comprising Brazil, Russia, India, China and South Africa keeps increasing its global market share yearly (35.2% in 2012 to 37.2% in 2013). In 2013, China alone accounted for 25.3% of vehicles produced and attests to the unambiguous direction and transition towards the east in relations to production and consumption of vehicles. The influence of local workers unions and powerful lead firms on the internal politics of countries has invariably necessitated OEMs to voluntarily limit exports and rather setup local production Sturgeon *et al.*(2009). This is advantageous to the automotive OEMs because local suppliers' products will intrinsically possess local content requirement giving them a better competitive advantage Veloso *et al.* (2000). Other variables leading to greater integration and globalisation of the automotive industry are public policy, consumer taste, purchasing power, environmental regulations and design modification of vehicles to use poor quality fuel in especially developing countries Sturgeon *et al.* (2009). A study conducted by KPMG in 2010 revealed that lead firms in the automotive industry are going to steadily increase their global sourcing activities in low-cost countries due to the cost saving opportunities that they provide. Ghana as a developing nation can strategically take advantage of this by placing itself within the material providers supply chain within the automotive industry.

3.4.2 Application of Non-Crimp Fabric Composites in the Automotive Industry

The use of glass fibre in the automotive industry started in 1953 where Chevrolet first introduced them in the Corvette. In 1962, Lotus sports car built one of the first European cars out of Glass Fibre Reinforced Polymer (GFRP). Chevrolet again incorporated glass fibre mat thermoplastics in their 1975 model Monza while Formula 1 cars switched to carbon fibre monocoques in 1981 Ehrenstein (2006). Aluminium remained the most preferred material for lightweight construction in the automobile industry until the late

1990s when fibre-reinforced plastics research and application received prominence as a viable alternative to metals Derks *et al.* (2007).

Currently, NCFs are hardly used in mainstream mass produced automobile parts because of the lack of an automated process chain. Only 5000 pieces per year are possible using resin infusion methods although the automation of performing and resin transfer moulding process can lead to the production of over 50000 pieces per year. NCFs are therefore mainly used in sports cars (formula 1) and luxury vehicles. The first batch produced NCF parts were the roof carline for the BMW M6 and the BMW M3's roof which was made from woven fabric and glass NCF. This resulted in a 5kg reduction in weight when compared with conventional roofs. The BMW Group, Munich, Germany, uses hybrid methods in the manufacture of some parts where NCF performs are glued manually on body-parts to improve mechanical properties to satisfy crash standards and stiffness requirements. For example, the side frame of the BMW Hydrogen7 was produced with this procedure Derks *et al.* (2007). Lamborghini designed two (2) boot lids for the Gallardo spyder, using aluminium and NCF. The NCF design was seen to be the most advantageous because only 2 single parts were required while the aluminium design required nine (9) single parts Derks *et al.*, (2007). NCFs tend to display low drapability, which limits its use in producing parts with very complex geometries Grundmann, (2009) and therefore a lot more research into solving the drapability issue and mass production possibilities are required to establish NCF as mainstream option else its use will remain limited Sköck-Hartmann and Gries (2011).

3.5 Non-Crimp Fabric Composite in the Wind Turbine Industry

3.5.1 Global Trend

Clean energy investments has hit a record high of USD 310bn (EUR 277bn) with the wind energy sector enjoying 11% investment rise of USD 99.5bn (EUR 88.9bn). In 2014 the wind industry set a new record for a single year by installing 51 GW of wind turbine power translating into a global total of 370 GW, however with China alone installing 23 GW, it led Asia to overtake Europe and become the leader with the highest wind capacity deployment GWEC (2014). European Wind Energy Association EWEA. (2015), projects that by 2030 the EU is expected to have installed about 320 GW of wind energy capacity which translates into 24.4% of the electricity requirements of the EU worth €474 bn. This also means that 96,000 wind turbines offshore and in-land would have to be installed. The direct benefit is that 436 million tonnes (Mt) of carbon dioxide (CO₂) emission will be avoided. With Brazil as the leader, the Latin American wind energy market has tripled in size since 2013 at an approximately 80% installed capacity growth. South Africa finally became a regional player in the African wind energy market in 2014 by installing 560 MW while Morocco installed 300 MW making the Tarfaya Project Africa's largest wind farm. West Africa is the only region lagging behind in the wind energy market. The potential for growth is huge in Africa because of the favourable wind conditions across the continent. The best technical winds in descending order can be found in East Africa (170 PWh/year), North Africa (130PWh/year), Southern Africa (110 PWh/year), West Africa (40 PWh/year) and Central Africa (10 PWh/year) (IRENA, 2014)

3.5.2 Prospects

Wind energy is a renewable energy source receiving a lot of attention. However, because of high maintenance and repair cost, the reliability of the wind turbine is of paramount importance in its design. They are expected to work efficiently for 20 to 25 years and hence durability is essential as a design consideration. The turbine blades must be capable of withstanding external loading (flapwise loading and edgewise bending loads), gravitational loads, inertia forces, pitch acceleration induced loads and loads due to torsion. The two moments; flapwise and edgewise bending loads are responsible for 97% of blade damage Thomsen, (2009). The part of that consumes the most composite in the wind turbine is the blade and its properties determine the reliability and lifetime properties of the wind turbine, making the rotor, the most expensive component Mohamed and Wetzel (2006). Turbine blades must be able to withstand extreme loads from environmental factors such as hurricane and earthquakes and therefore blade material must

possess high strength and stiffness, low weight, high resistance to fatigue and environmental loading. Composites are therefore the most favoured option and, in particular, NCFs Mishnaevsky (2011).

NCFs are mainly used in the manufacture of the turbine blade because of the complexity of the blade shape and production flexibility Vallons, (2013). As long as the following factors; energy security, insulation from fossil fuel price shocks, cost stability, creation of jobs, lower price, clean air due to reduction of CO₂ and deployment speed exists, interest in wind energy will continue to grow and hence demand for NCFs for the turbine blades will continue rise.

4 INTERVENTIONS, AND INNOVATIVE APPROACHES:THE SOUTH AFRICAN AUTOMOTIVE INDUSTRY

The South African automotive industry is facing severe completion and challenges similar to the Ghanaian textile industry. The difference, however, is the approach the two countries are using to ensuring sustainability and competitiveness in the local and global market. The South African automotive industry is thriving while the Ghanaian textile industry fails. A brief study of the South African model reveals practical and innovative strategies that can be adopted for use in revitalizing the Ghanaian textile industry.

The 2015 South Africa Automotive Export Manual revealed that South Africa ranks 24th in global production of vehicles and commands a market share of 0.63%. The global influences and competitive nature of the industry imply that the South African local suppliers must have access to comparable technology and deliver world-class quality as those in Europe and Japan. Locally the automotive industry is one of the most vital sectors of the economy because it employs, creates jobs, contributes 7.2% of the GDP, accounts for 11.7% of all exports and drives the manufacturing sector with 30.2% of all outputs. To ensure increasing employment in the automotive component sector, South Africa has chosen to focus on export as the domestic market alone cannot sustain the sector to achieve this purpose. The global market is expected to grow to about 3% over the next 10 years, making it imperative that South Africa attracts new investment options and OEMs to increase export volumes. The above scenario necessitated the review of the Automotive Production Development Programme (APDP) and the establishment and implementation of the Automotive Supply Chain Competitiveness Initiative (ASCCI) in 2014. The National Association of Automotive Component and Allied Manufacturers (NAACAM), National Association of Automobile Manufacturers of South Africa (NAAMSA), Department of Trade and Industry (Dti) and National Union of Metalworkers of South Africa (NUMSA) through the ASCCI initiative are collaborating with the aim of increasing supplier manufacturing value-addition to aid in the production of 1.2 million vehicles per annum by 2020. This initiative will ensure growth, competition, job creation and transformation of the sector to ensure sustainability and improve its global market share to over 1%.

The Dti plays an important role in the promotion of economic development and meaningful participation in the global economic and trade environment. The Export Promotion Directorate of the Dti is responsible for developing and promoting South African goods and services, including specific technical interventions in the form of Export Marketing and Investment Assistance (EMIA) financial support, matchmaking, market intelligence, trade lead facilitation and in-market support.

5 SIMPLIFIED UNIDIRECTIONAL MODEL FOR SUSTAINABILITY AND GROWTH OF THE GHANAIAN TEXTILE INDUSTRY.

A review of literature from Nitschke (2011), Berger and Rothschild (2008), Kaggwa *et al.* (2009), Barnes and Morris (2008), Barnes and Kaplinsky (2000), Black (2009), Ellis (2008), and DTI (2010) on the south African approach for ensuring sustainability and growth in their automotive industry as shown in figure 6 was generated as a proposed simplified model for reviving and introducing innovation into the Ghanaian textile industry. For continued growth and sustainability, seven Key factors were identified namely, the role

of government, Direct foreign investment, Local content, access to raw materials, the requirements of the Textile industry (Value chain and supply chain), demand from both international and domestic markets and identification of the key access markets.

6 LESSONS

From the discussions and the proposed model, it can be observed that the Textile Industry cannot thrive without in isolation and managed by only the private sector. Because of its importance in generating employment and possible prospects on impacting the GDP of a developing country like Ghana, inputs from all stakeholders is a major requirement for the industries survival. The most critical ingredients for success in accessing the engineering market are Conducive economic incentives and policies from Government, ensuring local content, capacity building within the textile industry and injection of resources from domestic and foreign direct investments.

7 CHALLENGES

The full potential and advantages of using NCFs can be achieved only if the entire manufacturing process from cutting, handling, draping to performance fixation is automated. The current system of production which combines manual and semi-automation is limiting while infusion resin systems also present the unique problem of low and unpredictable damage tolerance behaviours. For aircraft purposes specifically, this problem really limits the use of NCFs. However Promising and encouraging results are emanating from research currently underway on the use of thermoplastic particle insertions in textile composites. With the proper material selection of particles and an optimised approach to the insertion process, high-impact resistant laminates .

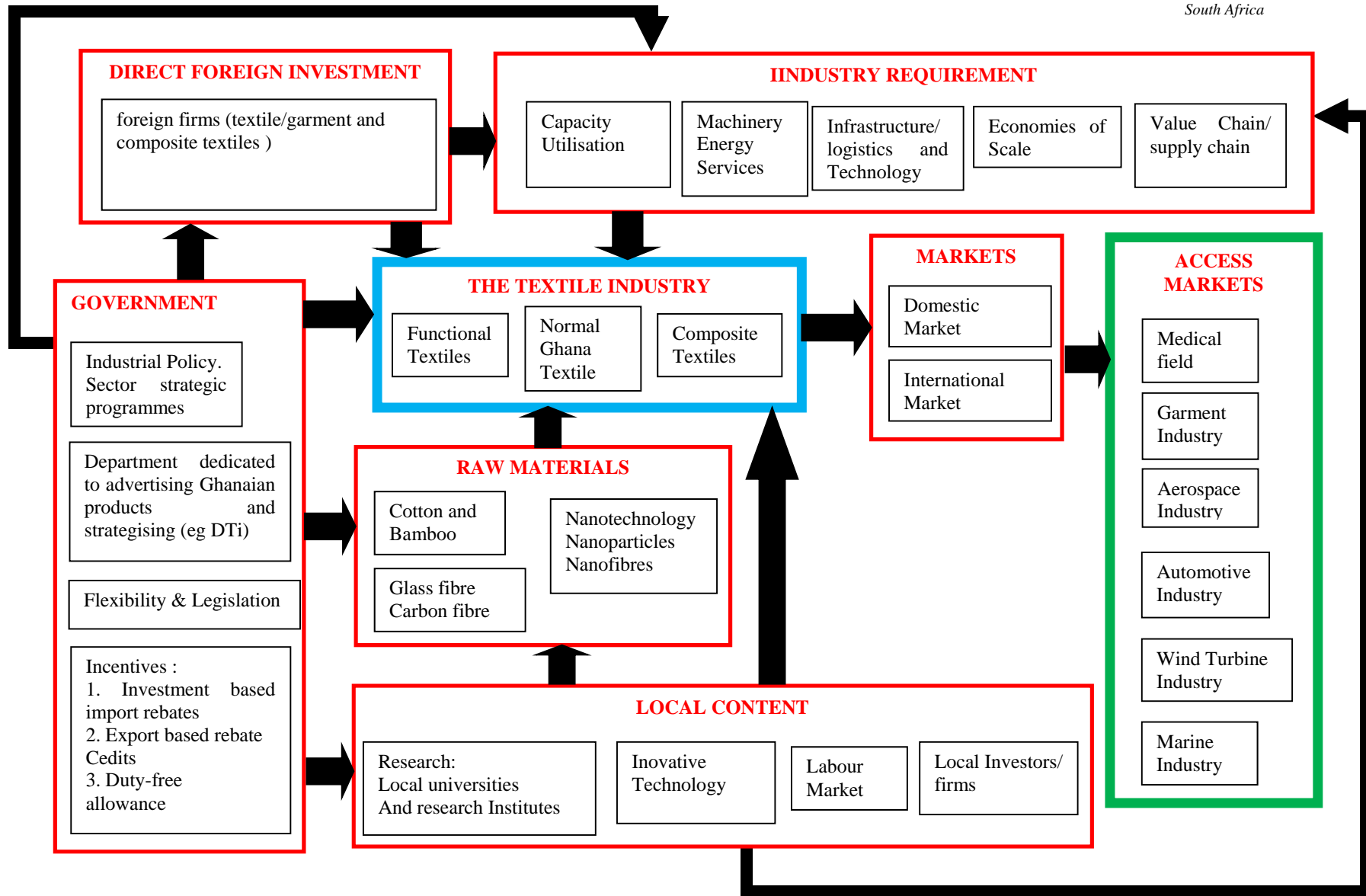


Figure 6. Proposed Model

8 CONCLUSION

The global demand for composites such as Non-crimp fabrics will continue to rise as research consolidates to automate the entire manufacturing process and optimize production parameters to suit specific use. The infrastructure of defunct textile companies are available for transformation into world-class facilities for NCF production in Ghana. The proposed model would not only open new engineering market to the Ghanaian textile industry but also lead to the establishment of new sectors that will provide the raw material need and auxiliary services. The government must play its part by voting funds, creating favourable economic environment, incentives and policy roadmaps to attract OEMs and local and foreign investors to ensure such a radical reformation works.

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