DPRU INDUSTRIAL STRATEGY PROJECT: PHASE TWO

WORKING PAPER 7

LEARNING, TECHNICAL CHANGE AND THE TRADE REGIME IN THE SOUTH AFRICAN AUTOMOTIVE COMPONENT SECTOR

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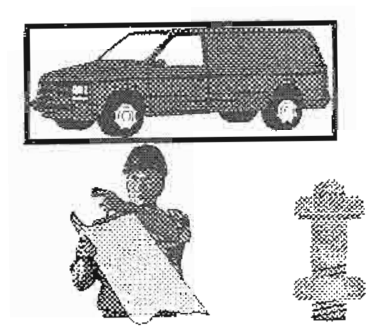

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Foreword

The first phase of the Industrial Strategy Project commenced in 1992. The Project has its origins in the Congress of South African Trade Union's (COSATU) efforts to develop policy responses to the malaise afflicting South African manufacturing.

The first phase of the ISP submitted its final report in 1995. This comprised 11 sectoral studies, a number of cross-sectoral studies, and a synthesis volume that proposed an overall industrial strategy for South Africa.

The ISP is now in its second phase and comprises four research themes. One of these examines the relationship between industrial development and the environment, a second focuses on firm-level innovation, a third examines issues in human resource development, and the fourth is concerned with identifying mechanisms to strengthen manufacturing competitiveness at regional and local levels.

This paper is one of a series of studies that examine mechanisms and capacities for innovation in selected South African firms. Certain of the firms chosen for this study have a demonstrated record of success in international markets, while others have been more constrained in their innovative capacity. The research attempts to derive lessons from their varying experiences that will help guide industrial policy and corporate strategy. These micro studies will be complemented by a survey of innovation in some 250 manufacturing firms. This survey is the product of collaboration between the Industrial Strategy Project and the Foundation for Research Development and will be published in February 1997.

These are working papers intended to catalyse policy debate. They express the views of their respective authors and not necessarily the Industrial Strategy Project.

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EXECUTIVE SUMMARY

One of the key determinants of success as an economy opens up to international competition is the effectiveness with which existing firms are able to adjust from being protected, high cost producers to becoming effective competitors with foreign firms in domestic and overseas markets. This outcome is far more important, at least in the short to medium term, than the emergence of new firms and sectors which may occur in response to fresh opportunities resulting from a more open economy. The mechanisms by which firms adjust are complex but clearly firm level capabilities play a key role and these in turn are contingent on the past pattern of development in general and the nature of protection in particular. This report examines how technological capabilities in the automotive component sector have been shaped by past policies of protection and more recently by the lowering of tariff barriers and also how these capabilities determine the capacity to adapt successfully to the challenges of international competition.

Section 2 examines the nature of technical change and learning in developing countries. Firms need to invest effort in acquiring technological capability. Incremental changes in all stages of the production process are collectively more important than major jumps in the form of the introduction of new technologies. The trajectory of technical change in developing countries also differs in important ways from that in the industrialised countries because of differences in industrial structure such as smaller markets and relatively higher levels of protection. The result is that the thrust of technological activity may be on overcoming obstacles such as low volumes in the domestic market and a weakly developed supplier base. Competitiveness measured in terms of unit production costs may therefore not be a good indicator of technological capability.

The global automotive component industry is being affected by a series of major structural shifts. Assemblers are reducing the number of first tier suppliers and these suppliers are being required to take greater responsibility for design. In South Africa, the impact of global developments is amplified by trade liberalisation. Section 3 sketches the background to the later case studies by illustrating how the structure of the industry was shaped by protection and is now being re-shaped by tariff liberalisation.

Past policies of protection have led to a fragmented production structure with both assembly and component firms unable to realise economies of scale. Protection has also had implications for the trajectory of technological development in terms of the investments undertaken, the degree of automation and the type of learning processes within firms. For example, in the era of protection, firms had to serve a market characterised by low volumes and wide variety. They became highly proficient at producing for this market but at costs well above international prices. So while considerable learning took place, costs were high. The lack of specialisation had implications too for the development of design - firms relied on licensed technology as low volumes could not justify large investments in R&D. Firms tended also to be vertically integrated either because the supply base was weakly developed or because components were too expensive.

The onset of tariff liberalisation is shattering this structure. As the case studies show, firms are rapidly embarking on major changes - refocusing their product lines and expanding exports as traditional markets shrink, revamping their shop floor practices to improve productivity and investing in upgrading their supply networks. These processes are examined in a series of case studies in section 4. The first case study (Atlantis Diesel Engines) is of a state owned engine plant which previously received monopoly protection. The firm has acquired significant technological capability but faces major problems in responding to massively increasing foreign competition. This case study focuses on the transfer of foreign technology, learning through exporting and the importance of incremental improvement.

Demanding customers are important in raising standards of production and this is particularly the case in the automotive industry where best

practice increasingly involves assemblers working closely with component suppliers. This is the objective of the reorganisation of the Toyota supply system which is examined in the second case study.

At Gabriel, a medium sized shock absorber producer, significant and ongoing productivity improvement has been achieved through upgrading work organisation. The case study of brake manufacturer, Alfred Teves, illustrates the importance of economies of scale and shows how firms attempt to adapt to the problem of complexity and short production runs.

As far as policy is concerned, the promotion of improved work organisation and inter-firm co-operation would appear to be particularly valuable. As far as more direct forms of technological support are concerned these should be focused on upgrading production capabilities rather than direct support for R&D.[1]

[1] Many people have assisted in the course of this project. I am particularly grateful to all those from automotive companies who granted interviews or assisted with information and to Dave Kaplan who provided extensive constructive comment at various stages.

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1. INTRODUCTION

In an article published in the Harvard Business Review in 1989, Magaziner et al give a compelling description of the entry of the Korean conglomerate, Samsung, into microwave oven production in the early 1970s. The firm advanced from scratch with small teams of engineers working all night in poorly equipped laboratories producing the first simple prototype which promptly melted when switched on. But the engineers persisted and in less than 20 years Samsung had become the world's largest producer of microwave ovens. Samsung is an exceptional company in a country which has achieved particularly rapid growth. Nevertheless, the fact that stories of this type happen rather more frequently in Korea than in South Africa would go a long way to explain the much more rapid expansion of manufacturing in Korea and the other NICs.

Bell et al's (1982) case study of the "very protracted infancy" of a Thai sheet metal producer sketches a very different scenario. In the four measures of production efficiency used there was no significant improvement over a period of nine years. The firm's technological resources were minimal, just sufficient to operate the plant. There was no attempt to upgrade these capabilities. Even though the firm employed 540 people it had no R&D section and did no R&D work.

Firms will always differ and examples of the above two extremes could be found in most countries although the Samsung case is much less common than the Thai example. However, the Samsung-type case is likely to be considerably more prevalent in high growth countries such as Korea and Taiwan than in say Argentina or South Africa. Of greater importance for growth is the probability that the <u>average</u> Korean firm is likely to be more dynamically innovative than the <u>average</u> South African firm.

Recent literature on technical change in LDCs has shifted from a view of technological dependency to one which points to the substantial amount of technological activity that goes on in developing countries as illustrated by growing exports of sophisticated manufactured products, technology and capital equipment.

This finding is no longer contentious and the key areas of debate are now the main forms of acquisition of technological capability and how these are affected by factors such as the industrial structure and the trade regime as well as by more direct policy interventions. Part of the large differences in the technological achievements of firms in similar circumstances relate to their own technological effort - but why does this vary between firms? Are the reasons purely idiosyncratic? Can government create a greater and more widespread culture of technological advance within the productive units of the economy and if so, how?

It is a widely held view that South African manufacturing firms are not on the whole very technologically dynamic. Indicators are relatively low levels of R&D and low patenting activity in international markets. This lack of dynamism is manifested in low productivity growth and low export/import ratios of technology intensive products. The motor industry which has historically been highly protected is generally regarded as less technologically dynamic and even more reliant on foreign technology than most other sectors. These limitations are becoming increasingly apparent as firms seek to re-orient themselves towards greater global competition. It therefore follows that policy needs to address this problem. But the issues are complex and not very well understood even in the context of advanced country manufacturing let alone developing countries and SA in particular.

This study investigates the processes of learning and technological accumulation in an industrial sector which is being rapidly opened up to international competition - that of automotive components. It explores the technological and learning processes that go on within firms and links these to the broader economic environment. The methodology is to analyse how the sector is reacting to both international and domestic developments and in particular to make use of a number of detailed case studies.

The study shows that learning and the accumulation of technological capability in the automotive industry under previous policies of protection have been quite significant. However, much technological effort has been 'mis-directed' in the sense that it has aimed at countering the problems that arise from a small protected domestic market rather than to achieve production efficiencies in high volumes which would enable it to compete in the price competitive international market place.

The acquisition of technological capability is multi-faceted. In developing countries in particular, large R&D departments with corporate scientists dreaming up smart inventions are really only a small part of the picture. The reality is more mundane, about small improvements and adaptations, about firms learning over a period of years how to achieve optimal output from imported machinery, how to adapt these processes to local conditions and occasionally to develop their own improvements. The small R&D departments in South African firms do hit upon major breakthroughs and there are firms which are world leaders but for the most part it is the small incremental, difficult to measure improvements which are the key to enhancing productivity. What is important in a country like SA is less that there are some firms at the cutting edge but that the broad mass of firms should be learning fast......and catching up.

Section Two raises some issues around the question of technical change, learning and innovation in developing country manufacturing. It explains how the particular conditions in developing countries, in particular small protected markets, produce a trajectory of technical change which is different in important respects to that occurring in developed countries. This has important implications for their capacity to adjust to global competition. This is clearly apparent in Section Three which outlines how policy has impacted on the structure of the South African automotive sector. The implications of international developments in the supplier industry are also assessed.

The main section (section four) analyses the process of learning in a range of automotive firms. Use is made of case studies which may be quite limited in terms of their generalisability but which assist us in understanding the accumulated capabilities of firms and the implications this has for their capacity to adjust to increased foreign competition. It illustrates that while these firms have developed significant capabilities in a protected environment, these capacities are not necessarily well suited to global competition. The concluding section considers the implications for policy.

2. TECHNICAL CHANGE IN LDC MANUFACTURING

2.1 The Character of Technical Change in LDC manufacturing

Research on technological change in LDCs in the 1970s was focused on the choice of technique and how this was affected by factor prices. There was also a widely held view that LDCs were technologically dependent. In the 1980s, a number of important studies emerged many of which were based on detailed case studies of firms in Latin America and Asia[2]. These studies pointed to the substantial technological activity in developing countries even in low growth, inward oriented economies such as those of Latin America. This was evident in rapid productivity improvement in some protected industries and evidence of growing levels of industrial competence as indicated by the capacity to undertake more complex tasks and growing exports from developing countries of sophisticated manufactured products, technology and capital equipment. These findings are now self evident and have precipitated a fundamental rethink of the process of technical change which is summarised below.

Following Bell and Pavitt (see Figure 2.1), it is useful to distinguish between two key resources which impact on industrial output: production capacity and technological capability. Any manufacturing firm has a certain production capacity, the components of which are its fixed capital, the operating skills of workers and management, its organisation of production etc. (or factors of production in the conventional sense).

Technological capability on the other hand refers to the capacities required to generate and manage technical change. This includes the knowledge, skills and experience of workers technicians and managers and also institutional structures. These capabilities are accumulated through learning which is therefore of fundamental dynamic importance as it impacts directly on the capacity of the firms to generate and manage technical change which occurs in two main ways - through the introduction of technology embodied in new product or plant and, perhaps more importantly, through incremental adaptations and improvements.

[2]. See for example Katz (1987), Lall (1987). For a review of the literature see Herbert-Copley (1990).

2.2 The Nature of Technical Change

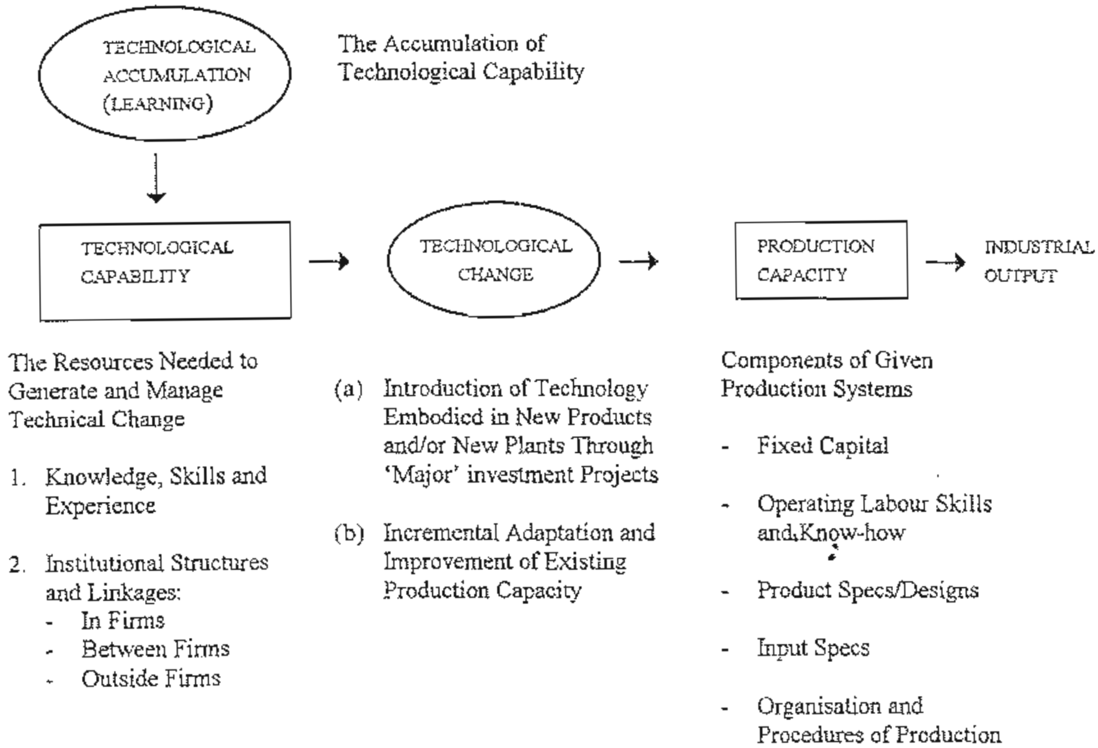
The brief outlining of this approach allows us to highlight some key characteristics of technical change.

Technology is tacit - the neo-classical assumption of a pre-existing shelf of available technologies which can be easily transferred makes little sense. Technology is by its nature tacit (Nelson, 1988). It is not fully codified and effort is required in transferring even well established technologies into new situations.

Technical change requires effort by firms - any form of technical change requires effort by the firm in question. Firms need to undertake technological effort by investing in training, organisational change, technical improvement and other forms of learning. For example, a firm buying a new turnkey plant will have to invest considerable resources in operating it at optimal capacity. The same applies to the development of new designs, the introduction of new production organisation or the introduction of minor new machines. The point is that while these technologies may be well established among international firms, transfer is not costless and automatic and the receiving firm needs to expend resources to make optimal use of new techniques.

Learning does not automatically arise from doing. Production experience is necessary for the acquisition of technological capability but it is not sufficient. Bell and Pavitt (1993) argue that increasing specialisation has widened the gap between the knowledge required to operate certain technologies and that required to change them. From this it follows that in late industrialisation, doing is a less effective method of learning. Learning takes place in a variety of ways. Absorptive capacity is an important requirement for learning to take place whether it be to cope with the introduction of new capital equipment or a new form of production organisation.

Figure 2.1: Conceptualising technical change: a schematic approach



Source: Bell and Pavitt (1993:164)

The importance of incremental changes - there are important processes of learning and technical change going on within LDC firms. The acquisition of technological capability takes place through incremental changes which are collectively in most cases more important than major jumps in the form of the introduction of new technologies. So technological activity takes place in all aspects of the production process. Lall (1987) for example breaks down technological activity into five constituent elements namely pre-investment choice, project execution, plant operation; technological improvement and technology transfer. Desai (1984) uses four categories of technological capability - capability in purchase of technology; plant operation; duplication and expansion; and innovation (cited in Reddy and Zhao 1990: 291).

2.3 The Direction of Technical Change

The trajectory of technical change in semi-industrialised countries differs in important ways from that in the developed world (Katz, 1984). This stems from two main reasons. Firstly, the economic conditions and industrial structure are very different in semi-industrialised countries and, secondly, these countries are not at the forefront of technology but are followers in industrial development. The differences in industrial structure include the following (Katz, 1984):

* markets are smaller
* levels of tariff protection are higher
* levels of automation are likely to be lower with the use of older vintage capital equipment
* the level of concentration of industry is likely to be higher with limited competition in a wide range of sectors
* acute market imperfections (e.g. skills shortages) may exist
* the network of supplier firms is poorly developed.

Limited markets and protection mean that plants are frequently small in relation to those in developed countries and economy of scale issues are a key consideration in technical choice. This implies the need to scale down to smaller plant size and diversify product mix requiring in turn simpler more universal, lower capacity machinery. This frequently leads to discontinuous technology and low levels of automation. A key problem of adjustment for firms being exposed to greater competition and trying to break into export markets is to make the leap from a discontinuous flow situation to a continuous flow mass production scenario (Katz, 1984).

The small size of LDC plants affects the technology initially selected. Continuous flow highly automated technologies are not appropriate because of the size of LDC plants and in some cases as a result of operational complexity. In products such as vehicles and components where continuous flow is necessary, firms in LDCs can "end up with the worst of all worlds - that is, with a small continuous flow 'line' turning out a highly diversified output mix, intended for various small individual markets." (Katz, 1984:117). The complexity of small batch production and high levels of machine down time all add substantially to costs.

Katz (1984) also points to the weakly developed layers of subcontracting firms which result in higher levels of vertical integration within the firm than would be the case in developed countries. This reduces the level of technological specialisation and is also likely to result in the underutilisation of installed capacity.

As a result of a differing production structure, the focus of technological activity differs between advanced and developing countries. In the developed world, cost minimisation is likely to be central and the effort to gain a technological lead is also likely to be important in certain types of firms. These are important objectives for competitiveness and are also likely to be important in developing countries. But firms operate under different parameters in developing countries. For example, a prime concern is with the transfer of process and product technology and the achievement of quality standards where the benchmarks are set in the developed world. In a real sense these firms are followers. They need to learn and master processes and technologies which have been developed elsewhere. So technical change is heavily focused on adapting imported technology to local market conditions. It tends to be ad hoc and incremental as new machines are added and adaptations made.

The view that industrialisation behind tariff barriers is quite likely to produce non-innovative, undynamic and inward-looking enterprises has now become the conventional wisdom on the subject. There is certainly much evidence for this perspective and the automotive industry in highly protected developing countries is a prime example. However, there is a growing body of research especially in Latin America which indicates that it would be an oversimplification to cast most firms in protected industries within this category. Many of the firms within industries may be technologically quite dynamic within the parameters in which they operate with rapid learning taking place and a considerable accumulation of technological capability. However, the distortions introduced by the trade regime may mean that much of this effort is mis-directed according to benchmarks of international competitiveness. An example is the vast amount of effort in areas such as logistics, materials flow, machine changeovers and production scheduling that is undertaken in order to deal with the problems of complexity that arise in low volume, multi product plants which characterise the automotive and component industry in developing countries. They have thus become well-adapted (over-adapted?) to the circumstances of captive, protected markets - what Pinela et al (1992) refer to as the 'platypus effect'.

Considerable technological effort is expended in adapting to specific domestic conditions. The problem, therefore, is not so much a lack of technological effort but the fact that cost minimisation and achieving optimal potential from world scale plant is not the central thrust of technological effort.

Lall (1987:11) states it in the following way:

> "A firm's technological efforts may be highly successful in resolving the problem it confronts, and may signify a greater basic capability than another's which is more competitive internationally. However, the first firms efforts may have been directed at overcoming obstacles rather than improving competitiveness."

These preliminary observations will be shown to have a clear resonance in the South African case studies in Section 4. In contrast, the East Asian NICs prioritised the installation of world scale plant from an earlier stage which has assisted in compressing the catch up phase of industrial development. It is, therefore, not surprising that they have been particularly successful in the mass production of scale intensive products, precisely where much of South American (and South African) industry has been weakest.

3. THE AUTOMOTIVE COMPONENT SECTOR

3.1 Global Technological Developments

As is the case in vehicle assembly, the components industry is undergoing major structural changes and new forms of relationship between assemblers and component suppliers are developing with important implications for developing country producers[3]. The American and European mass producers have traditionally dealt with between 1 000 and 2 500 suppliers whereas Japanese assemblers generally have less than 300 even though they outsource a larger proportion of components. In the Japanese system, these first tier suppliers carry a far greater responsibility for the design and development of an entire sub-assembly such as the braking system, and in turn draw on a range of second and third tier suppliers for individual components. The relationship between Japanese assemblers and suppliers is far less adversarial with relationships being developed over a long period and component suppliers being closely involved in the development of new models from the initial stages. American and European firms are now rapidly adopting elements of this system with the number of suppliers being reduced and key firms being required to take greater responsibility for research and development.

These developments draw on the Japanese system with modifications according to the strengths of the local industry. Taken together they amount to a new *modus operandi*, what Lamming (1993) calls the 'post Japanese model' of component supply. According to Lamming the major elements of this evolving model are :

* fewer, larger component suppliers with greater technological capability.

* a supplier industry increasingly structured into tiers dependent on the capabilities of firms and the nature of their links to assemblers. First tier suppliers will supply whole

[3]. See for example Lamming, 1993.

assemblies or systems (e.g. a complete door assembly) directly to assemblers and will have extensive R&D capabilities. They will in turn draw on second tier firms for sub-assemblies such as a window winding mechanism and to third tier suppliers for more minor components such as plastic mouldings or a single metal stamping (see Figure 3.1). Raw materials will be provided by the fourth tier.

* stronger and more co-operative vertical relationships between companies in the various tiers and between first tier suppliers and the assemblers.

* more developed horizontal relationships with an expansion in various forms of partnership such as joint ventures and technology and supply agreements.

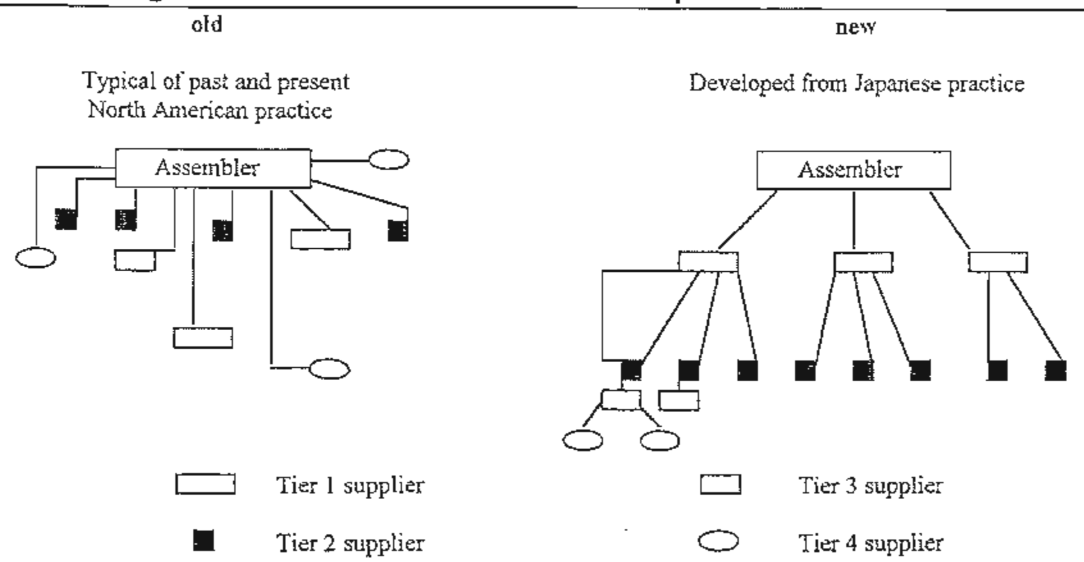
* major suppliers will have to accompany assemblers to new locations in order to be able to supply on a JIT basis.

* first tier suppliers rather than assemblers will increasingly undertake sourcing from low wage countries.

* attaining competitive advantage will require the adoption of best practice in terms of working practices and technology.

The post Japanese model of international component supply suggests, therefore, that firms that wish to supply components directly to the vehicle assemblers should themselves have significant capacity to undertake product development work.

Figure 3.1:
Vertical integration models in automotive components



Source: Science Council of Canada (1992:5)

The question is where these trends in the global industry leave the automotive component sector in the developing countries. Taking greater responsibility for product development is a major leap for the component sector in advanced countries - it is difficult to envisage LDC based automotive component producers which have little capacity for design and innovation achieving this status. Nevertheless, the demands on developing country suppliers are increasing rapidly as assemblers adopt world sourcing strategies and as opportunities open up for exports to international markets. In many developing countries the supplier base is being consolidated with fewer suppliers to assembly plants. As is happening in the developed world, first tier component producers increasingly supply complete sub-assemblies to vehicle manufacturers. In countries such as Brazil and Argentina, assemblers are also investing heavily in upgrading the supplier base (Addis, forthcoming; Posthuma, 1995).

Table 3.1:

Assembly firms operating in South Africa

Assembler	Ownership	Make(s)	Market share	
			Passenger cars	LCVs
BMW	BMW AG	BMW	7.6	-
Delta	Domestic	Opel Isuzu	10.2	16.3
Mercedes Benz	MB AG	Mercedes Honda Mitsubishi	11.3	5.0
Automakers	Sankorp	Nissan Fiat	14.3	19.5
Samcor	Ford	Ford Mazda	12.5	19.9
Toyota	Wesco	Toyota	20.7	32.0
Volkswagen	VW AG	Volkswagen Audi	22.8	6.0

Note: Data on market share are based on sales by domestic producers for 1995.
Market share is share of local production only and excludes imports.
Ownership indicates management control.

3.2 Structure of the South African Automotive Industry

The South African automotive industry produced just under 400 000 cars and light commercial vehicles in 1995 an increase of nearly a quarter on 1994. Approximately 4% of production was exported. There are seven assemblers producing passenger cars in South Africa. As indicated in Table 3.1 most of these firms are also engaged in the assembly of light commercial vehicles (LCVs). The majority also produce more than one make.

Past policies of indiscriminate protection have predictably resulted in a crowded assembly industry and an extraordinarily large range of makes and models being locally assembled. In the passenger car and light commercial assembly sector there are approximately 35 different basic models. Average annual model[4] production volumes are only approximately 11 500 which is much lower than even in low volume producing countries such as Australia (50 000) and Brazil (30 000). Low volume runs have not been conducive to the development of the domestic supplier industry because they cannot achieve the economies of scale necessary to minimise unit costs. The resulting uncompetitiveness of the component sector has discouraged assemblers from increasing local content beyond required levels. High local content levels (currently the average is 55%[5]) have never been achieved except in certain higher volume, smaller vehicles.

There is an unusually high degree of local ownership in the South African assembly industry (see Table 3.1) but the autonomy of locally owned firms is heavily restricted by the fact that they rely on licensed technology. While locally owned firms have considerable autonomy in operational decision making and marketing they face restrictions in exporting. With South Africa's reacceptance into the world community and the increased internationalisation of the industry, local assemblers are becoming more integrated into the global networks of their parent/licensor companies. For example, the German parent companies (BMW, Mercedes and VW) are planning to incorporate their South African subsidiaries into their global

[4] A model is defined here as all vehicles produced off the same platform and excludes derivatives.

[5] This is according to the measurement of local content under Phase VI ie. wholesale price less foreign exchange used. It therefore includes assembly overheads and profit margins. Actual local content is lower (40-45%).

sourcing strategies. Ford has reinvested in Samcor, Nissan Diesel (Japan) has taken a small equity stake in Automakers and Toyota Motor Corporation has taken a significant minority stake in Toyota South Africa. Decisions by the main international producers are therefore likely to have an increasingly significant impact on the future of the industry.

Component Manufacture

There are approximately 250 component producers in South Africa. The industry is, however, fairly concentrated with the 10 large firms/operating groups which employ over 1000 workers accounting for around 50% of employment and a greater proportion of output.[6] In addition to the above , a number of the vehicle assemblers also have significant in-house component production of engines, pressed parts, trim and other components.

~~The South African~~ automotive industry produces a full range of components. However, the cost of locally produced components is generally higher than the landed (before duty) cost of imported components. Price differentials vary but until recently were of the order of 20-30%. The main reasons for the cost premium are low volumes which result in a lack of economies of scale (see figure 3.2) and also high costs in the domestic market for materials such as steel, aluminium and rubber. However, the domestic component sector is competitive in certain components as indicated by areas of particular export strength. These include raw material intensive[7] items such as alloy wheels, castings, catalytic converters and automotive leather as well as a range of other minor components. South African producers are also competitive in sectors of the aftermarket especially niche markets for run out parts where the capacity to produce small runs becomes a competitive strength. Electronics firms, some using capabilities developed in the armaments industry, have been successful with high tech products in export markets.

3.3 Government Policy and the Development of the Industry

Tariff protection and local content requirements have been central to the development of the industry. In most respects, South Africa followed a programme of import substitution similar to that adopted in other developing countries especially in Latin America. High tariffs were placed on CBUs which when combined with a rapidly growing market acted as a magnet to a large number of (initially foreign) companies which established operations in the country. These operations, although in many cases highly profitable, were very small in international terms and with correspondingly high unit costs. Production was aimed solely for the domestic market and the South African assembly plants were kept isolated from the global production networks of the parent companies except as markets for CKD packs.

The domestic market expanded rapidly in the post-war period. Levels of local content were low, however, and the adverse effect of large scale component imports on the balance of payments led to the introduction of a series of local content programmes from 1961. Local content requirements were gradually increased to reach 66% under Phase III of the local content programme which was introduced in 1977. Tariffs on vehicles during this period were at prohibitive levels with imports restricted to a small number of exotic vehicles.

[6] This is at the level of the the firm or operating group. Thus large groups such as T&N Holdings and its subsidiaries (Asseng, Ferodo, Silverton etc) are part of the same operating group. The level of concentration would be higher if control was taken up to the level of the final holding company (conglomerate/financial institution).

[7] Exporters are normally able to obtain raw materials at international prices.

FIGURE 3.2:

Examples of the scale of production in South African components producers compared to international producers

Body pressings - SA firm makes 1000 different components. Press shop in Japan would typically make 150 with much higher total volume.

Alternators, starter motors, electronic control units - SA firm produces 300 000 alternators per year. German parent company has established new plant in Wales with a capacity of 8 million alternators per year. The SA plant producing electronic control units is more suited to low volume production as it is organised on a cellular basis. A European plant would be similar but with a larger number of cells replicating a similar production process.

Exhaust systems - largest SA plant is one third of group's largest European plant and makes a larger variety of products.

Steering Wheels - SA plant has capacity of 300 000/year compared to 2 million in German plant which produces a smaller variety.

Pistons - SA producer uses 5 lines to manufacture a wide range of pistons at a rate of 60 000 per month. Current batch size of 500 is being reduced to 200. A US based piston producer in the same world-wide group uses 7 highly automated lines to manufacture only 7 variants but has a capacity of 600 000/month.

Electronic vehicle security systems - SA manufacturer can achieve R50m turnover in the export market with two part numbers compared to 210 part numbers to achieve the same level of turnover in the domestic market.

Various components - Major automotive holding company with several component subsidiaries have conducted a survey of parts produced which indicated that less than 5 percent of the various parts produced were in volumes of more than 2000/month.

Source: Black (1994)

The problems inherent in the above approach to the promotion of local content had become obvious during the 1970s and 1980s. In spite of some mergers and disinvestment during the 1980s, the industry remained extremely fragmented. Exports were minimal and with the increased introduction of highly sophisticated components, it had become increasingly easy to meet mass based local content requirements while increasing the value of imported components.

Phase VI, introduced in 1989, represented a significant change in direction. It marked the first attempt to address the problem of an overly fragmented industry with low volume output and associated high unit costs. Most importantly, local content was to be measured not just by the value of components fitted to locally assembled vehicles but on a net foreign exchange usage basis. Assemblers were therefore able to reduce actual local content in domestically produced vehicles if they achieved high export levels.

Exports of components have risen rapidly and in this regard the programme has been extremely successful, although factors besides Phase VI have played a role. The growth trend has been dramatic and the local content value of exports of components has risen sharply from R139 million in 1988 to R2.45 billion in 1995[8]. Many component suppliers and all the assemblers have instituted significant export programmes. The assemblers have developed international marketing channels frequently via their overseas principals and identified the types of components where local producers have a competitive advantage.

South Africa's main export market for automotive components is Germany (mainly original equipment components). An important factor has been the strong ties established through the three main German car producers all having assembly plants in South Africa. However, the sector remains highly import intensive with approximately 55% of components used in locally assembled vehicles being imported. Vehicles imported on an SKD/CBU basis will account for nearly 10% of sales in 1996.

For vehicle and component producers, foreign ownership or a joint venture arrangement with a foreign firm conferred some advantages under this new scenario. Foreign owned firms have in many cases been quickly incorporated into the world-wide sourcing arrangements of the parent company. Most domestically owned firms are equally dependent on licence agreements with foreign principals but face the problem of restrictions on exports in terms of these agreements.

Rapidly rising exports have given assemblers considerably greater flexibility in their sourcing arrangements and traditional component suppliers have come under increasing competitive pressure. Components with high tooling costs and low production runs were particularly vulnerable. Components which formed part of sub-assemblies were also at risk because it became easier and cheaper to import these in a semi-assembled form thus simplifying assembly and limiting the problems of local quality and supply complexity and re-engineering. A further problem with Phase VI is that it failed to rationalise the industry in any way. Because nominal rates of duty on vehicle imports remained high while the flexibility of component sourcing increased, the effective rate of protection on assembly actually increased leading to additional model proliferation.

The Motor Industry Development Programme

The trends that developed under Phase VI are likely to accelerate with the introduction in 1995 of the Motor Industry Development Programme (MIDP). Table 3.2 indicates the duty reductions in the MIDP. Although nominal duties on imported vehicles remain fairly high, firms can rebate duties by exporting and so for the first time local vehicle producers face serious competition from imports. The component sector also now faces greatly increased international competition. Under the new programme, there are no local content requirements and the component sector will be protected by (declining) tariffs. Assemblers also receive a duty free allowance which permits duty free importation of components up to the value of 27% of the wholesale value of a vehicle. Exports can also be used to offset duties on imports.

The pressures of international competition will lead to some rationalisation of the large number of models produced in the country although it is unlikely that there will be a reduction in the number of plants in the short term. Local assembly firms, especially those which are foreign owned are being drawn increasingly into the global networks of the parent companies and are likely to specialise in the production of a limited range of vehicles with a significant increase in exports. In the component sector, there is likely to be some consolidation and an increase in international tie ups as firms are forced to become competitive and export oriented. This is a wrenching change for firms geared up for low volume flexible production and the component sector is already in the midst of a major restructuring process.

[8] Exporters have been encouraged by the provision under Phase VI whereby exports were counted as part of the local content requirement and under the new programme under which the earning of export credits allows firms to rebate import duties (see following section).

A survey conducted in 1995 shows that while there will be winners and losers in the process, component firms are planning to increase investment and exports and aggregate employment levels are expected to remain stable (Black, 1995). It should be recognised, however, that the industry was experiencing boom conditions at the time of the survey with sales growing rapidly and this is likely to have influenced expectations about the outlook for investment and employment. In spite of the fact that two thirds of firms expect competition in their product line to increase dramatically as opposed to one third who expect the increase in competition to be slight or negligible, firms are generally adopting a positive approach.

Figure 3.3 illustrates that firms plan to upgrade productivity by improving production efficiencies, expanding exports and increasing investment. The restructuring process will, therefore, be centred around efforts to improve in-house productivity including work organisation, by attempts to expand production volumes in a more focused range of products through exporting and to upgrade plant and equipment including increased use of automation. Introducing new product/ process technology ranks fourth as a response to the new programme compared to being the fifth most important response to the old programme.

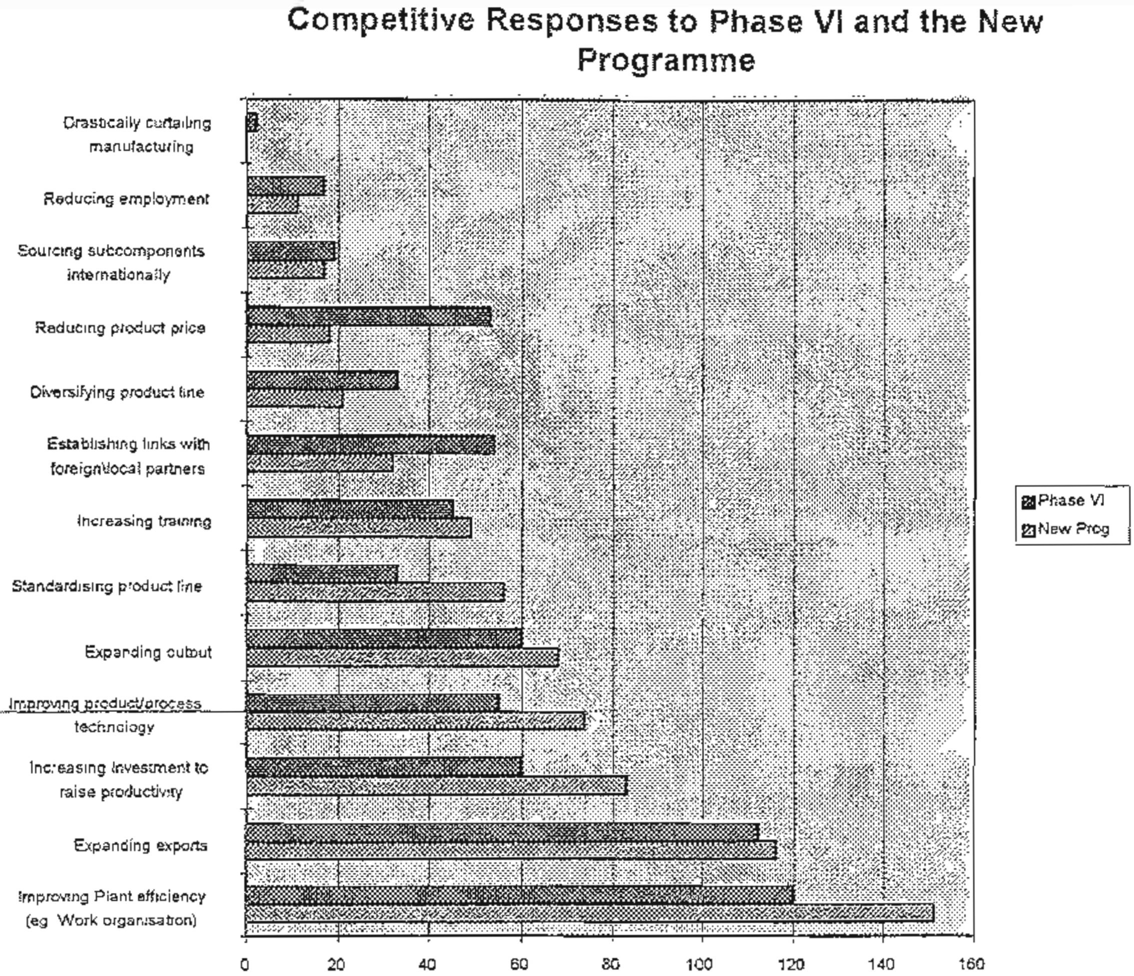
Of the 46 firms who responded, 83% are involved in exporting to some degree but the average percentage of turnover exported is only 11%. As indicated in Figure 3.4, 49% of firms expect exports to increase by over 10 % per annum in real terms over the next five years while a further 40% expect an annual increase in real terms of 1-10% per annum. Firms also expect investment to increase as indicated in Figure 3.5

Table 3.2

Tariff reductions under the MIDP

Year	Nominal Import Duty Level %	
	Built up vehicles	Components
1995	65	49
1996	61	46
1997	57.5	43
1998	54	40
1999	50.5	37.5
2000	47	35
2001	43.5	32.5
2002	40	30

Figure 3.3:



Note: Firms were asked to rank the five most important responses to the pressures and opportunities resulting firstly from Phase VI (introduced in 1989) and secondly expected to arise from the new programme (introduced in 1995).

Tariff reductions and the abolition of local content requirements have already raised the competitive pressures and are leading to increased outsourcing and reduced local content in domestically produced vehicles as assemblers develop global sourcing strategies. Automotive component firms are responding by seeking to improve production efficiencies, upgrade investments and raise export levels. The focus is on incremental changes to improve production efficiency and the upgrading of capacity and new technology through new investment. Rapidly rising productivity will be necessary to deal with competition and to sustain the export drive.

3.4 Technological Development

The South African automotive industry depends heavily on imported technology. The predominate form of technology transfer is through foreign investment (either wholly owned or on a joint venture basis) or through licensing. Although there is a high degree of local ownership, all the locally owned vehicle manufacturers and the bulk of locally owned component producers operate under licence from European, Japanese or American firms. This involves royalty costs and also imposes restrictions on export which have been a serious problem for some firms as the domestic market comes under pressure and firms are forced to develop export strategies. In spite of these disadvantages, the situation is unlikely to change in the foreseeable future and most firms

Figure 3.4:

Expected Real Annual Change in Exports

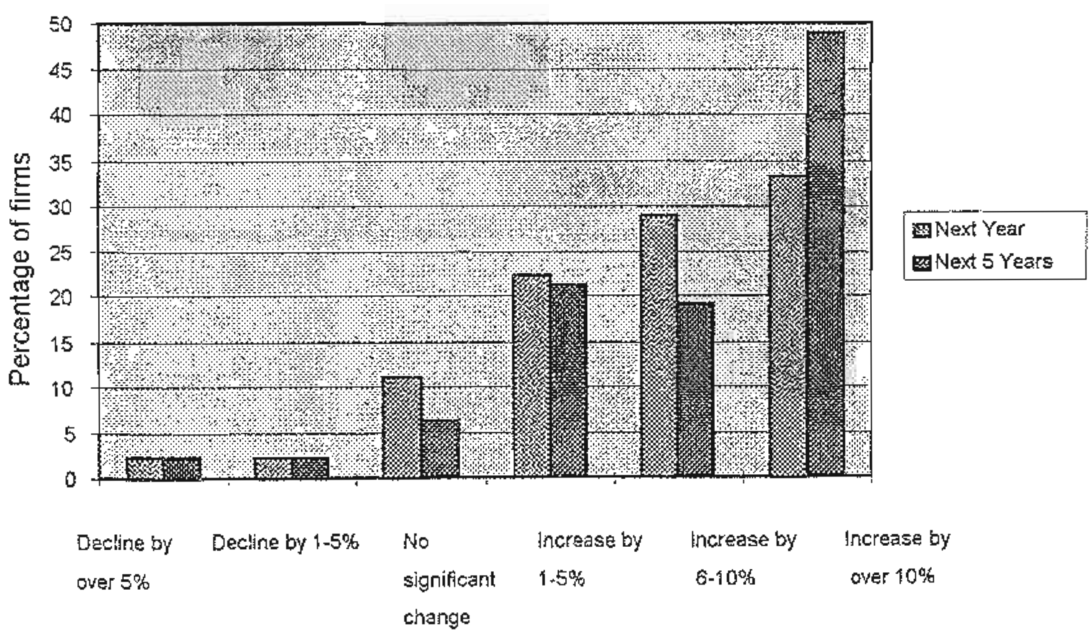


Figure 3.5:

Expected Real Level of Investment (compared to Average Levels over the Past Three Years)

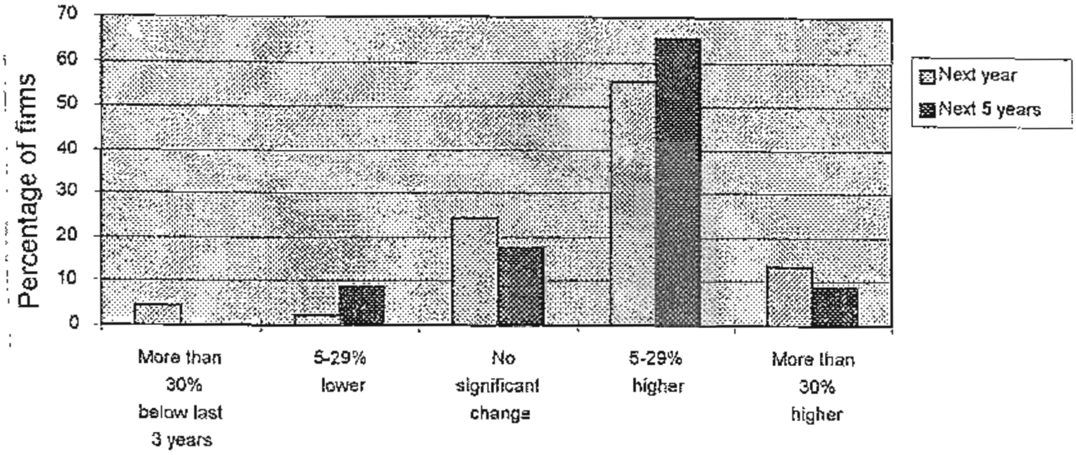


TABLE 3.3:

Component firm technological capabilities

Firm capability	Responses
Choose among alternative technologies	0
Utilise to designed standards	0.5
Extend beyond designed capability	1.0
Adapt technologies	5.5
Generate new products and processes	4.0

Note: Some firms fell across two categories which accounts for the half scores.
n = 11

Source: Black, 1994

consider licensing to be the most cost effective way to obtain up to date technology.

Developing their own technology is difficult for most component firms. In the case of product technology they are competing with multinational suppliers with huge R&D budgets. Among firms surveyed by Black (1994), R&D spending averaged 3% of sales, with the dispersion ranging from negligible amounts to 8%. But although firms spend relatively little on R&D and are generally highly dependent on foreign licences, they are by no means totally lacking in technological capacity.

Firms were asked to rate their own technological capabilities on a scale ranging from very limited capacity (the ability to choose among alternative technologies) to the capacity to generate new products and processes (Table 3.3). Most of the larger firms are able to adapt both product and process technology and even generate new products and processes. For the most part these are minor adaptations but in themselves are important in two ways. On the product side they illustrate the capacity for design even if only in a limited form. On the process side, the findings illustrate that firms are not only able to fully master the technologies they are working with but also to upgrade them by introducing adaptations.

A significant number of firms were also able to generate new products and processes. All these firms were locally owned (2 were independent) and most devoted significant resources to R&D. Most were specialised in terms of their product and they were generally much more oriented to exports than the sample average. Two were involved in the production of wheels and had developed their own designs and brand names. While quality is extremely important, the manufacture of wheels is not as technologically demanding as say gearbox assemblies and it is obviously a much easier industry to operate in without foreign product technology. Clearly this kind of opportunity is not open to South African producers of more sophisticated components.

Some domestic firms have been able to introduce innovations which are ahead of western competitors. One aluminium wheel producer, for instance, has introduced modifications to the die cooling system which reduced casting time to 180 seconds compared to 300 seconds in Europe.

As a consequence of high demand resulting from South Africa's high rate of car theft, one firm became an international leader in electronic vehicle security systems such as immobilisers and at one stage licensed code-hopping technology to Texas Instruments. However, the firm has been unable to maintain this technological lead because they could not match the resources of multinationals such as Siemens, Bosch and Philips which have come into the market. This kind of leadership is rare in the automotive industry and resulted from a fortuitous chain of events rather than pre-determined strategy. This also probably accounted for it losing its pre-eminent position as it lacked the requirements in terms of internal R&D capacity, sufficient volume and size which would have justified additional expenditure.

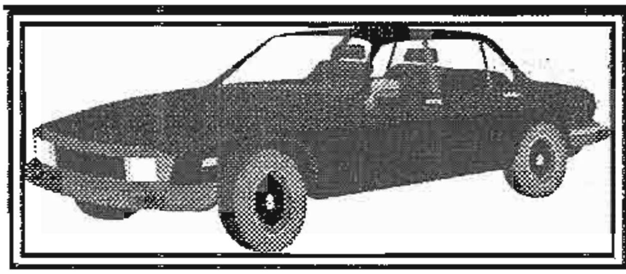
A number of firms are engaged in attempting to make machinery more flexible (see Chapter 4) and new equipment is chosen with this objective. Some important innovations have resulted from the experience of high variety, low volume production which characterises the South African components industry.

So, although firms for the most part are dependent on foreign licensors for new technology and spend little on R&D, there is a basic level of technological competence and clear capacity to introduce productivity raising technological adaptations. Furthermore, in some limited areas, component producers are relatively advanced. Some firms producing less sophisticated products have proprietary technology and their own brand names. There are also a small number of companies producing more sophisticated products, which also have their own technology. Some of these result from electronics expertise developed in the defence industry.

The strengths of the local industry are primarily in process development and there are numerous instances where process innovations developed in South Africa have been transferred to a parent company or licensor. Significant capabilities have developed over the past decades in investment and production capability, process engineering, quality control and workforce skills.

Apart from licensing, the main forms of technology transfer are through direct investment and the purchase of imported capital equipment. The growth in exports has also led to the upgrading of technology and the growing internationalisation of the industry has led to a number of informal transfers. The number of foreign technical experts and advisors working in South African assembly plants has also been increasing.

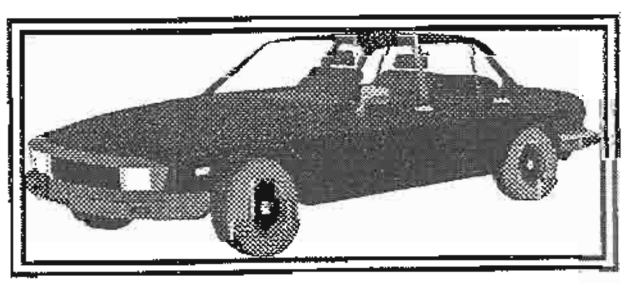
Certain adjustments are made to local vehicles to adapt them to local needs and purely South African derivatives have also been developed. Local adjustments include higher specification radiators and trim to deal with strong sunlight and higher temperatures, stronger suspension and superior dustproofing. A high level of standardisation in the use of medium and heavy truck engines has been achieved via very high protection for the state owned engine producer. This in turn required considerable modification of a number of truck makes to take the



Mercedes Benz engines produced under licence by the state owned producer, Atlantis Diesel Engines.

The impact of protection on quality standards and supplier capability is a complex issue. On the one hand, a long period of protection has enabled the local industry to acquire key manufacturing competencies in terms of production experience and quality. However, there is also no doubt that protection has created distortions which have negatively impacted on efficiency. An extreme example was the deliberate building of heavier components during the period up to 1989 when local content was measured on a mass basis. Heavy protection has also encouraged a proliferation of locally assembled makes and models with an associated requirement for a very wide variety of components in low volumes. South African firms have, as a result, achieved a high level of expertise in low volume multi product production. This technological capability is, however, of limited value in the international market place although it has meant that South African firms are competitive in certain low volume aftermarket and replacement parts. Growing international competition is likely to accelerate technological upgrading but the main conduits are likely to be through transfer from foreign sources rather than an increase in domestic R&D. Domestic firms under pressure to upgrade their technological and production capacities are turning to foreign sources through the establishment of joint ventures, for example, rather than making major investments in R&D.

The issue of complexity of specifications and standards poses a further problem for developing country industries. Staying at the world frontier in terms of new models, and emission levels imposes considerable costs in terms of required investments in new tooling. However, falling behind makes it difficult to penetrate export markets both for vehicles and components although it may allow one to supply run out models and components to selected niche markets. South Africa faces particularly difficult choices in this respect as it is trying to increase exports to both highly developed countries and into the rest of Africa where the demand is for rugged, less sophisticated vehicles.



4. CASE STUDIES OF FIRM LEVEL LEARNING[9]

All firms in the following case studies have a history of a long period of protection but now face increased foreign competition in the domestic market and the need to expand exports. In common with the rest of the component sector they are also confronted with the problem of a fragmented domestic market and associated demand for a wide variety of components in low volumes.

This section focuses on the process of learning and the upgrading of technological capability at firm level. The key issues addressed are the main areas of technical change, the factors driving these changes and how firms are responding to a globalising economic environment. This effort might be directed at a number of objectives including:

- the introduction of licensed technology
- new investment
- incremental improvements and adaptations of processes and products
- improved work organisation
- expanding exports
- upgrading the network of suppliers

All of these are illustrated in at least one of the following case studies. The first case study (Atlantis Diesel Engines) is of a state owned enterprise which previously received monopoly protection. The firm has acquired significant technological capability but faces major problems in responding to massively increasing foreign competition. This case study focuses on the transfer of foreign technology, learning through exporting and the importance of incremental improvement.

Demanding customers are important in raising standards of production and this is particularly the case in the automotive industry where best practice increasingly involves assemblers working closely with component suppliers. This is the objective of the reorganisation of the Toyota supply system which is examined in the second case study.

The case study of brake manufacturer, Alfred Teves, illustrates the importance of economies of scale and shows how firms attempt to adapt to the problem of complexity and short production runs. At Gabriel, a medium sized shock absorber producer, significant and ongoing productivity improvement has been achieved through upgrading work organisation.

4.1 Atlantis Diesel Engines: Reorienting Production from Domestic to Global Markets

Atlantis Diesel Engines is a large state owned[10] engine producer. Together with its affiliated companies, ADE manufacture diesel engines, castings and components for the automotive, agricultural and industrial markets. Its core business activities are:

* Manufacture (casting, forging and machining) of six major diesel engine components (cylinder blocks, cylinder heads, crankshafts, camshafts, connecting rods and flywheels) for the domestic and export market.

* Assembly of diesel engines in the 30 to 450kW power range for local original equipment manufacturers, primarily for truck and tractor applications. The firm also undertakes remanufacture of diesel engines and components.

* Manufacture, supply and distribution of ADE replacement parts to the local market and distribution of industrial diesel engines and parts (2 to 1000 kW) to South and Southern Africa.

ADE was established as a strategic industry in 1981 as South Africa's political isolation deepened. It provides a fascinating case study of South African manufacturing industry in

[9] Most of the fieldwork for these case studies was conducted during 1995.

[10] The Industrial Development Corporation owns 87.5%; Mercedes Benz AG, 12.5%.

transition. In the early stages, the viability of the plant was ensured by a virtual prohibition on imports. The initial objectives were production capability of a wide range of products to high quality standards with production costs and profitability being lesser considerations.

The plant was designed with an annual capacity of 45 000 engines (two shifts) divided into two engine makes (Perkins and Mercedes Benz) and the capability to produce a wide model range. World scale diesel engine plants produce in excess of 100 000 engines a year of a single make with a smaller model range. High production costs put exports out of reach and the slump in demand in the early 1980s led to severe underutilisation of capacity. Thus ADE represented an extreme form of the inefficiencies of protection in an industry where economies of scale are important.

Strategic direction

ADE recognised six years ago that that it had to change and the company is now half way through the transformation process from a monopoly engine supplier to component exporter. This process involved firstly a major internal focus on costs which has enabled ADE to sharply reduce engine prices in real terms since 1990. Secondly, the company has sought to define areas of competitive advantage - which in its case are forming and adding value to metal rather than assembling engines. So the objective became one of gradually moving out of engine assembly to become a world class flexible manufacturer of main engine components such as crankshafts. These competitive advantages arise out of the skills that have developed and also the nature of existing investments. For instance, the forge is designed for a particular size of crankshaft and some of the machining facilities are flexible.

Faced with these pressures, ADE has been through an accelerated process of improvement in plant efficiencies which have built on the production capabilities established in the era of high protection. In the earlier phase, the emphasis was on the accumulation of investment and production capability. The major source of technology was licensing which although expensive was regarded as the only viable source of technology. Innovation has been directed at adapting processes to lower volumes but increasingly is focused on improving efficiencies in higher volume output in line with the shifting strategic direction of the firm.

The Licensing of Foreign Technology

ADE manufactures engines and components under licence from Mercedes Benz and Perkins and from its inception has relied on foreign technology and expertise. At the initiation of the ADE project, it was decided that South Africa needed to produce diesel engines in the 35-735kW range and seven producers were approached to present proposals to the Industrial Development Corporation. Mercedes Benz and Perkins were the only two that could offer the full spectrum together.

The licences cover trade and manufacture with the manufacturing licence supported by agreements on technical assistance, collaboration and supply. The agreements cover specific engine types and their derivatives. For example, in the case of Perkins there was a master agreement plus supporting agreements for the 3, 4 and 6 cylinder engines that were to be manufactured under licence.

Licensing costs involve three elements:

* an initial fee for the right to manufacture which is paid when the plant is established
* a technical assistance fee
* a royalty which is based on a formula according to the number of engines and components produced.

There is also a supply agreement by which ADE undertakes to purchase requirements at a pre-determined price. Imported components can be replaced with local components as long as quality standards are met. The initial agreement was for 10 years and is renewable.

ADE is quite clear about the reasons for going the licensing route and does not anticipate moving heavily into product design. It regards licensing to be a far more cost efficient method of getting access to technology in spite of the costs and the restrictions it imposes. Engine development is extremely expensive. For example, to design a new engine family similar to the existing one would cost Perkins with its established expertise some £60m. The alternative of ADE allowing licensing agreements to lapse and going its own route would mean the loss of technical support resulting in the freezing of the level of engine development. The Polish firm, Kamaz, used to produce under licence from MAN and a number of Indian truck makers have also gone this route but according to the financial director "if we (ADE) ever have visions of developing South African designed engines, we should kill them immediately......it is virtually impossible".

Nevertheless, licence arrangements are expensive. The initial licence payment to Daimler Benz in 1981 was DM 10 million. This was an upfront fee giving ADE the right to manufacture. In addition there is a royalty of 1-3% of the engine/component selling price. In the case of Perkins the initial fee was £100 000 per engine for three models of engine. A fourth was later added at a cost of £250 000. Additional payments for technical assistance were made as this was required. These payments have fallen sharply as ADE developed its production capabilities.

Acquiring Investment and Production Capability

In the early stages, the Mercedes and Perkins plants were run as separate operations. The infant company was very reliant on its licensors. In the case of the Mercedes plant, early operational decisions were in the hands of Finasco, a finance house set up by the IDC. Mercedes Benz provided information on what was required and recommended suppliers but the purchasing decisions were made by Finasco. ADE itself had nothing to do with the initial purchase of equipment.

Expatriates from Mercedes Benz AG were initially responsible for getting the factory running. They were gradually replaced by staff from ADE who received training in Germany. The length of time taken for expatriate staff to be replaced by local ADE management partly reflected the importance attached to particular functions by the licensor. Process technology capabilities were quickly acquired and transferred while the licensor kept greater control over product technology, skills which in any event would take much longer to transfer (Table 4.1).

Table 4.1

Localisation of management at ADE

Management function	Time taken to replace expatriates with local ADE management
Maintenance	Almost immediately
Production	3 years
Manufacturing engineering	3 years
Quality	12 years
Product engineering	13 years

In the case of the quality function, the licensor wished to maintain some control. Product engineering management was really responsible for application engineering and the adaptation of engines to a variety of trucks with basic design being carried out by the licensor.

The acquisition of investment and production capability can be divided into three phases.

Phase 1 The first phase involved the licensor advising on the choice of equipment. Partly as a result of this and partly because of demand projections which proved hopelessly optimistic they adopted dedicated equipment. Some of the initial technology was fairly dated because the licensor thought this would be appropriate for African conditions. This has caused problems. For example, some of the initial machinery purchased made use of switchgear even though NC or CNC machinery was available at the time.

Phase 2 From the mid-eighties all planning was done by ADE with Mercedes Benz "looking over their shoulder". For example in 1985/6 ADE needed to introduce a new engine block because of local content requirements. They approached Mercedes Benz for advice. According to an ADE manager, "MBAG responded that you use a big transfer line which takes up a whole building and produces one block every 1.8 minutes and our requirement was one block every six hours." Therefore ADE did the planning themselves. This involved process innovation in the sense of adapting flexible technology (using a machining centre to perform all operations) to conventional technology. This was a lengthy process but eventually worked and the process technology went back to Mercedes in Germany who use it in the production of low volume engines.

Phase 3 Since 1990 ADE have been able to carry out all investment decision making and planning themselves and have developed full investment capability. The licensor no longer tests engine components produced by ADE - a privilege which has to be earned through investment in people and technology.

Today, ADE's capacity to select technology appropriate to its operating circumstances is highly developed. In line with its strategic direction, it is specialising in certain technologies involved in the manufacture of crankshafts, blocks and cylinder heads as well as forging and casting. Use is also made of external consultants in selected areas, a recent example being induction hardening technologies. In the future, the company is likely to move more into process design. Product design is not a priority the view being that there would be little purpose in "reinventing the wheel."

Export expansion

According to the senior general manager for exports "by 2000 ADE will be out of the truck engine business". As a result of falling tariffs, local truck manufacture is giving way to SKD assembly with much lower levels of local content. The commonisation process which virtually required South African truck makers to use ADE engines is being reversed. As its share of the domestic engine market is likely to drop rapidly as protection falls, the future viability of ADE will depend on the extent to which it is able to remodel itself as a component exporter. Export growth has been rapid with exports for 1995/96 of R120m up from R20m in 1989/90. ADE exports are in two main areas - machined engine blocks (cast) and crankshafts (forged). Exports have enabled ADE to achieve the volumes necessary to produce components which are not just of a high quality but also competitively priced.

Export expansion has been achieved in spite of the limitations that licensing places on exporting. All exports need the licensors' approval and engines cannot be sold outside the Southern African Customs Union unless they are already installed in a vehicle. The licensors are more flexible with component exports and exports back to the licensors account for a significant proportion of export turnover. This requires that ADE keeps up with changes in specification. They have chosen this route rather than limiting engine changes even though this may result in savings in terms of investment costs. The small MBAG stake does mean that ADE has a close relationship with its licensor but nevertheless the licensor will always favour a wholly owned subsidiary.

The reorientation towards exports involved a steep learning curve and the company found it very difficult initially. Exhibiting at international shows was unrewarding. Export contracts have been secured through contacts with licensors and networking rather than mass marketing drives. For example, ADE have recently negotiated a substantial contract with the Korean conglomerate, Daewoo. The initial approach was made by the Korean firm and arose out of Daewoo discovering that another Korean company Ssangyong had bought components from ADE.

Quality and reliability are the two key issues in exporting. Once these have been achieved, then price becomes a key factor. The global industry is relatively small and a company's reputation is of great importance. According to the export manager, a senior director of MAN told him that he had "never dealt with a company which delivers products at the same quality level as ADE." This kind of reputation in the market place has led to further orders. Flexibility in supply and the capacity to up and down the schedule is also a competitive attribute. ADE also prides itself on keeping in close touch with customers. The incentives offered under Phase VI and the MIDP have been important to help fund investment in export capacity but the policy has been to export only if reasonable margins could be obtained without the incentive so that it is felt that taking away export subsidies won't adversely affect the export business.

Continuous improvement in the foundry[11]

The foundry was established to supply castings for cylinder blocks and heads and was designed to supply 80-90% of requirements for the planned engine capacity of 50 000 Mercedes Benz and Perkins engines per year. As was the case with the main plant, the major problem has been the underutilisation of plant capacity and the need to raise throughput and simplify product variety.

Initial design was a blend of technology in use for the range of castings to be produced. Total planned output of 12 000 tons/year is very small by international standards as most foundries have a capacity of over 50 000 tons per annum. ADE was also designed to produce an unusually large range of castings (approximately 20). By means of comparison, the Mercedes Benz Mannheim plant produces only 14 types of casting and has a capacity of 85 000 tons. These large volumes enable it to run three separate lines for small, medium and large castings. The South African plant, therefore, had to be more flexible requiring compromises, for example, in machine selection. Also the flask size had to be large enough to accommodate a range of castings. Although the plant was designed to be relatively flexible, higher volumes are a key objective and given the small size of the depressed domestic market, export is the key to success.

The casting process requires four separate operations - core-making, moulding, melting and finishing/fettling. Productivity improvement (figure 4.1) in all areas of the operation has taken place in three overlapping phases. The first was simply through the downsizing of employment. The second stage was to increase capacity utilisation by specialising the product line and then by making investments which both expanded capacity and increased productivity in selected areas of focus. The emphasis is now on continuous improvement.

From the mid 1980s, improved rates of capacity utilisation were achieved through exports and incremental investment which has enabled the foundry to achieve reasonable economies of scale. From the late 1980s, machined engine blocks which were exported to Perkins only on an overflow order basis were exported in volume (12 000 per year). By 1995, 40 000 engine blocks were being exported to Perkins of which 20 000 were machined.

[11] This section is based on an interview with the foundry senior general manager.

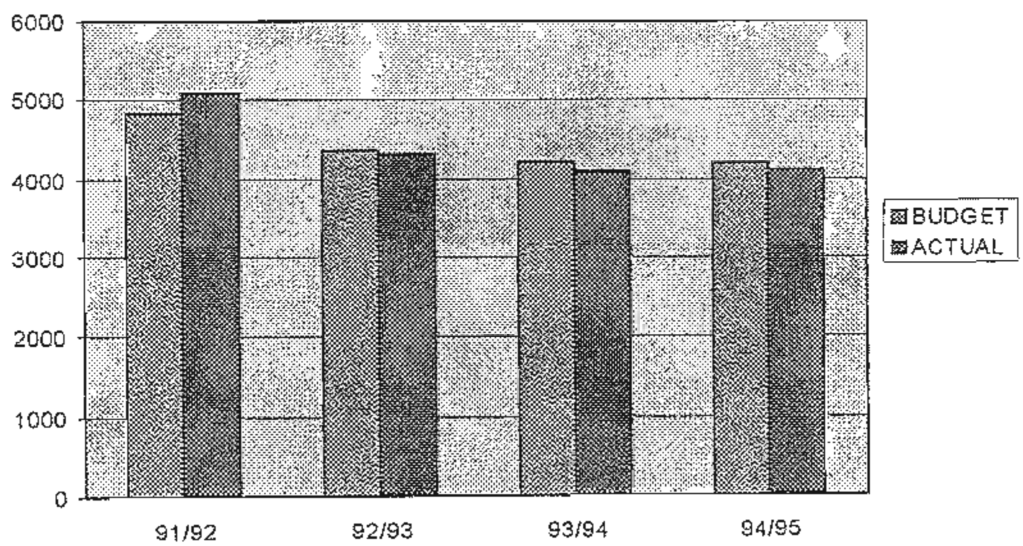
In 1990 a new pressure operated pouring furnace was installed which created the opportunity to synergise melting and moulding at the maximum output of the moulding capacity. This investment expanded capacity to 15 000 tons per annum and allowed ADE to service a new export contract to Eaton of 3000 tons of gearbox casings per year. From this stage, the foundry was exporting 60-70% of its output.

Exports of rough castings especially to Ssangyong will reach 130 000 blocks per annum by the end of 1996. Another large contract is with MAN in Germany and from 1997, ADE will be exporting machined Vblock crankcases.

The company has also invested heavily in support of a large export contract for Daewoo who have moved off licence and produce engines similar to Mercedes Benz. ADE will also be exporting cylinder blocks for Perkins' new engine model.

Figure 4.1

Atlantis Foundries: Total Cost per ton sold (Rands)



Source: ADE

As a result of the expansion of export volumes, the plant was working at close to its 12 000 ton capacity in 1995 working three shifts in some areas. The melting operation is presently operating at the limit of its capacity and is currently a constraint on production. As a result, capacity in the foundry is being expanded especially in the melting area. Current melting capacity of 6t/hr is being increased by 10t/hr although this will only be used at the off peak electricity rate (thereby adding an initial 5t/hr). Production is being increasingly focused towards the heavier end of the casting range requiring a higher mass per mould. The foundry is also investing in fettling and cleaning capacity. In all, investment projects worth R10m were underway in 1995 with a further R40m approved.

The three hubs of foundry technology are in North America, Europe and Japan. These rely on the large market and developed capabilities in all areas of foundry technology. For example the Bilbao area in Spain has developed as a centre of excellence in foundry technology built round the existence of a large pattern maker which provides tooling, a leading foundry equipment manufacturer which drives the process and a number of large foundries which provide for the testing of the process. The combination of these three has led to major advances in core manufacture and assembly and the patenting of a number of core making techniques.

ADE try to apply available existing technologies to specific operations. Formal and informal links with the licensor are important - for example, the foundry manager is in regular contact with his counterpart in Mannheim to keep up to date with developments. Through the licensor they get exposure to international developments. They lean on MB for seeing new technologies - MB tend to adopt new technologies more quickly and because they are launching more new projects are able to apply more innovations. So ADE is a follower, attempting to catch up rather than establish a lead. "Twenty years ago SA was probably 20 years behind - now just 2-5 years".

Initial technology for the foundry was a compromise. Mercedes Benz was used as a sounding board rather than complete technology transfer - and technology was selected from MB and Perkins with expertise from consultants. For later investments, use has been made of project management consultants, specialist foundry consultants such as the Swiss firm Georg Fischer as well as ADE's own experience. According to the foundry manager ADE "regard themselves as a little blinkered and use outside expertise to get outside the existing paradigm."

ADE do not do fundamental research and do not have a formal R&D department. However they have expertise in the selection and assessment of equipment and are constantly introducing improvements in process technology some of which incorporate their own innovations. The foundry now undertakes its own subassembly in the core shop and has found ways to integrate core assembly with minimum jointing. Another recent example is the shift away from hotbox methods to coldbox methods of coremaking.

Automation levels are currently quite low but the signing of large export contracts such as the one with Ssangyong justify further automation such as the possible introduction of robotic fettling. The new furnace plant uses the latest power sharing technology in induction furnace smelting in which a single power pack splits the heat to two furnaces - keeping the metal warm in one while melting with the other. This requires a higher level of operator skill (computer literacy).

Another recent development is to increase the number of castings per mould. It was traditionally common to manufacture in a single or twin (Siamese) mould. Where possible four castings using multi impression patterns are now being produced in a single mould. This allows ADE to use its large flask size to the optimum - but the technique is only suitable for export because large volumes are required to justify the initial investment.

The drive towards continuous improvement through the establishment of teams has led to major improvements.

As the foundry manager puts it:

> "by driving the objectives of the company in bottom line teams there is identification with specific goals, so in the teams you have output and other productivity drive goals that are tracked by the team. So its a self measurement of their own improvement - I think that has helped to build motivation and morale at team level"

ADE's initial attempts to introduce quality circles never really worked. The teams are now able to handle a variety of problems - for example if a backlog arises the team will develop solutions. Teams have come up with numerous suggestions for incremental improvement such as:

- improvements in the fettling process
- design of lifting hooks /chisels
- reducing labour required in the spotface
- machine used for pressure testing.
- reversing the order of assembling cores which led to better consistency and more rapid throughput.

No monetary award is given for these innovations although they may be celebrated by a special lunch, for example. However, incentive bonuses are paid four times a year and can amount to 8-10% of annual salary. Training has been increased and is more results driven and broader with 5 days per year the new minimum. This is seen as a start but not yet close to the world class norm of 10 days.

Conclusion

The restructuring of ADE has involved a process which probably approximates the restructuring of East European manufacturing operations in the degree of change required. From being a monopoly engine producer for the domestic market, ADE will soon be reliant on component exports for most of its revenue. Because of heavy protection in the initial stages, the changes associated with a more open trading environment have been all the more wrenching involving a complete reorientation of the production process which was initially established to supply a full range of engines at low volume. Plans now are to develop key areas of competency - cylinder heads and blocks - and to become an international player because, as the managing director puts it, "international markets are where (ADE) see economies of scale where we can drive through productivity gains." The ADE case illustrates that even though the nature of initial investments that took place made it impossible to compete internationally, learning has been rapid and with more appropriate investments, ADE has been able build a rapidly growing export business on the basis of its accumulated skills in core capabilities such as the manufacture of engine blocks and crankshafts.

4.2 Toyota - Upgrading the Supply Network

In any industry involving the assembly of large numbers of components, the strategy adopted by the assembler is of key importance. In the development of the automotive industry in Japan, the assembly firms played a key role in the development of ancillary firms. As indicated in section three above, best practice in the automotive industry increasingly involves assemblers developing closer linkages with component suppliers and providing them with technological assistance as well as devolving responsibility to them. This system, pioneered by Japanese car makers has now been emulated in Europe and the US. This link between assemblers and component producers is important both because it provides technological assistance to suppliers as well as placing demands on them to upgrade standards in terms of price, quality, delivery and in the case of first tier suppliers, the capacity to carry out research and development.

As Addis (forthcoming) has shown in the case of the Brazilian automotive industry, market liberalisation can also lead to new forms of industrial governance which encourage greater co-operation between assemblers and small suppliers. In Brazil this has taken the form of large firms promising long term contracts to small firms in return for improved productivity. Large firms have also acted as mentors over the restructuring efforts of smaller firms while smaller firms have worked collectively to upgrade their capabilities.

More co-operative relationships between assemblers and component suppliers have not yet emerged to any significant extent in South Africa except insofar as the industry is small and personal contacts play an important role. Most component producers do not receive significant assistance from assemblers and most firms do not see a more significant trend towards closer co-operation. Many regard the assemblers as expedient and short-sighted for moving swiftly to use foreign components and endangering the long term viability of the component sector on which the assemblers ultimately depend.

Phase VI, by encouraging the assemblers to seek component exports did encourage some collaboration at the same time as it gave some firms greater flexibility in sourcing. The MIDP will give further encouragement to both these processes. Firms, which are making use of local content either for export or for the domestic market will require these suppliers to upgrade their capabilities. In return they can offer access to higher volumes and export markets. BMW, for example, is planning a significant export programme and has specialised production in one model. The firm is encouraging German component-makers to take equity stakes in their South African licensees. This is likely to lead to an upgrading of equipment and technological capability in order to raise output and exports from these plants.

Another index of co-operation between assemblers and component suppliers is the just-in -time (JIT) system. JIT is not well developed in South Africa although a number of assemblers have introduced elements of the system for certain components. Constraints on the fuller implementation of the JIT system in South Africa include:

* the lack of high quality and reliable suppliers.

* low volume requirements for each model and the wide variety of products produced by component suppliers. More exacting JIT requirements by assemblers therefore generally result in simply shifting inventory costs onto component producers rather than removing them from the system.

* large distances between production centres.

The limited development of JIT needs to be kept in perspective, however. CKD packs which comprise a large proportion of the components used are imported from Germany or Japan with lengthy shipping times.

Toyota, South Africa's largest motor vehicle assembler has gone further than most others in developing its own supplier network. It is more focused into the local market partly because it has developed an extensive supply network both of in-house components and partly owned supply companies. So while Toyota will be developing world sourcing, it sees its local suppliers as stakeholders and has the objective of raising them to world standards.

Toyota, which historically has had close links through ownership ties with component suppliers, has activated a number of programmes aimed at upgrading the capacity of its component suppliers. The Toyota supply network includes a large number of wholly owned, partly owned and independent component producers. A number of activities such as seat manufacture, engine assembly and injection moulding take place on site. There are also a number of satellite plants. Toyota Automotive Components (TAC) produces components including seats, exhausts and canopies and accounts for approximately 14% of local components used in the production process. The Toyota Stamping Division (TSD) produces a further 13% of local components used.

Wesco, the holding company for Toyota (South Africa), also controls the listed Metair group whose subsidiaries produce airconditioners, wiring harnesses, batteries and other components. Forty seven percent of supplier firms (accounting for 51% of supplier turnover) are located in the Durban -Pietermaritzburg area in close proximity to the Toyota plant.

In the face of increased price competition which has already led to reduced market share, Toyota has introduced a two pronged strategy aimed at driving down component costs as well as improving quality and delivery. Domestic suppliers are not regarded as being very competitive, except in areas such as machined castings and aluminium wheels and in aftermarket components such as glass and radiators which generally require smaller investments. So while domestic suppliers are regarded as stakeholders, they will nevertheless have to compete and Toyota is aiming at cost reductions of 2.5-5% per annum. It is also increasing global sourcing from the international Toyota network. For example, engines for the Camry will now be imported from Australia. Clearly current local content levels of 52-55% are unlikely to be maintained at least for the lower volume models. Toyota had 137 external original equipment suppliers in 1995 down from 158 in 1991. It is likely that these numbers will be further reduced as a result of increased world sourcing following the abolition of local content requirements. Increased access to world-wide sourcing means that Toyota has been able to enforce a policy of no price increases during 1995.

The second prong of the supply strategy is aimed at upgrading the capacity of its supply network through various forms of assistance coupled with a detailed system of performance benchmarks to which suppliers will have to adhere.

These interventions take a number of forms:

1. For firms within the group, Toyota is very involved in the negotiation of licence agreements to ensure that exactly the right types of technology are secured. This is important particularly as there is little sign sofar of direct investment by Japanese component suppliers into the industry.

2. The firm has recently introduced the Toyota Supplier Assessment system which will benchmark all suppliers according to a detailed set of criteria. This will be one of the major criteria in future sourcing and will enable problems to be isolated and appropriate action taken (see below).

3. The Kanban system which already encompasses 66% of component suppliers by value is being extended. Toyota carries 2-5 days of inventory for kanban suppliers.

4. Attempting to reduce levels of CKD inventory on site by increasing the number of monthly sailings from Japan.

5. A Suppliers Council consisting of top suppliers has been established. It currently has 10 members. Quarterly meeting are held at which suppliers showcase their plants and the other members of the council have to critique it.

6. A Product Engineering Group has been established. It consists of *goshi* teams comprising engineers, quality specialists and platform teams who work with suppliers.

7. The Supplier Quality Assurance department provides audits on quality.

8. The Field and Tool Group provides technical support in Johannesburg and Port Elizabeth.

9. Japanese engineers are also used for supplier development.

10. A programme for encouraging sub-contracting to small firms has been put in place (see below).

The following discussion focuses on two of the above initiatives. The Toyota Supplier Assessment System is arguably the most important of the initiatives with suppliers and has the greatest potential to bring about extensive productivity improvement. Sub-contracting to small firms is currently seen as a development objective with little commercial benefit in the short term. But in the longer term small black owned suppliers are likely to be significant sources of supply particularly to major component suppliers.

The Toyota Supplier Assessment System

Toyota has developed a detailed system of supplier assessment which makes use of five basic criteria each with its own weighting. The criteria and weightings attached to them are best practice (25%), quality (20%), purchasing (22%), delivery (18%) and technical support (15%) (see Figure 4.2). Each of these criteria is in turn broken down into sub-categories. To score a high mark as a best practice supplier depends on the work practices that are in place (inputs) as well as on plant performance (outputs). On the input side the best practice manufacturing assessment takes account of the management system, corporate culture and the production system. Culture for instance includes the structure of the firm and criteria such as staff turnover, absenteeism, number of suggestions per employee and the percentage of the workforce in teams. A good production system rating requires the application of systems such as JIT, Jidoka, Heijunka and Standardised Work as well as meeting related performance criteria with regard to inventory levels, reject ratios and rework levels (see Appendix 1).

The criterion of technical support (15% of the overall rating) benchmarks firms according to engineering staff and structure, testing and laboratory facilities, *goshi* systems and the adoption of Toyota requirements (Figure 4.3). Interestingly there is little or no importance attached to design or R&D capability which would be a key requirement of a first tier supplier to Toyota's plants in Japan or the US.

Firms which achieve a minimum of 95% in the overall Supplier Assessment will qualify as preferred suppliers while those scoring below 65% will be regarded as unsuitable for business and will be required to make immediate improvements (see Appendix 2).

Figure 4.2 Toyota supplier assessment

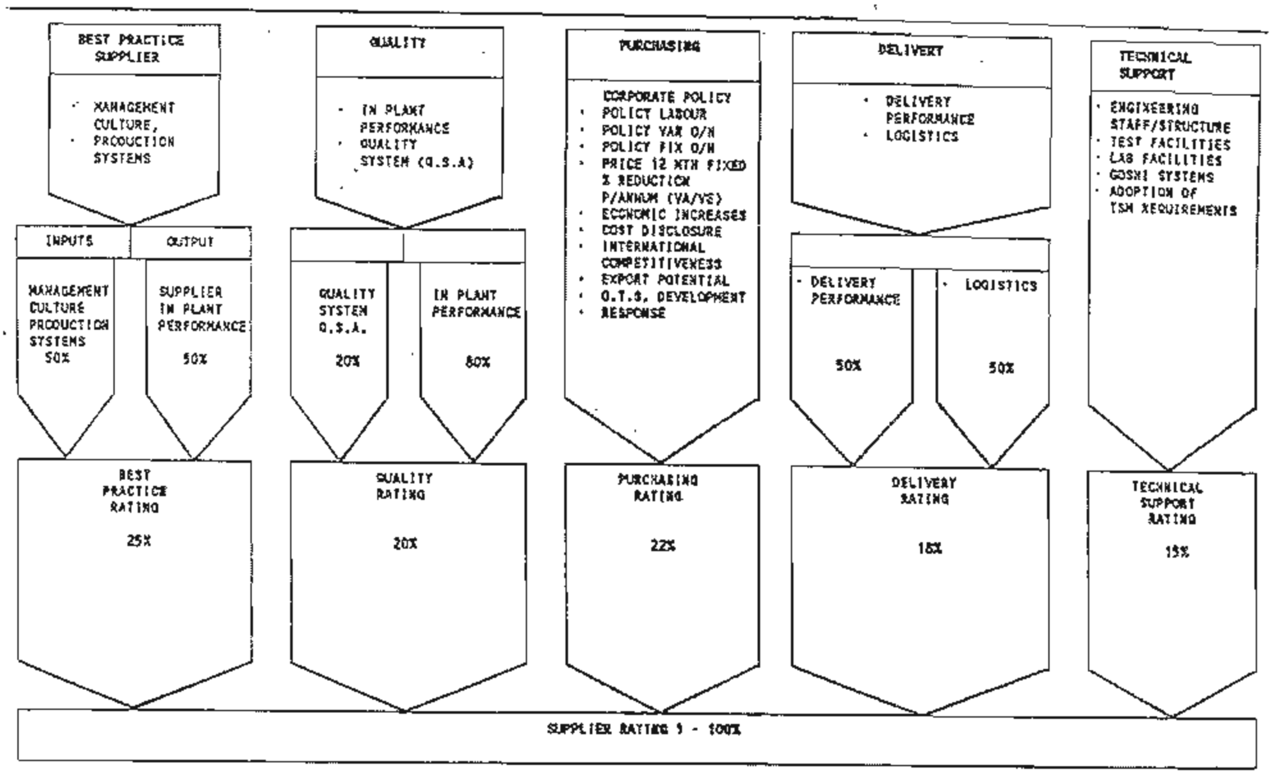
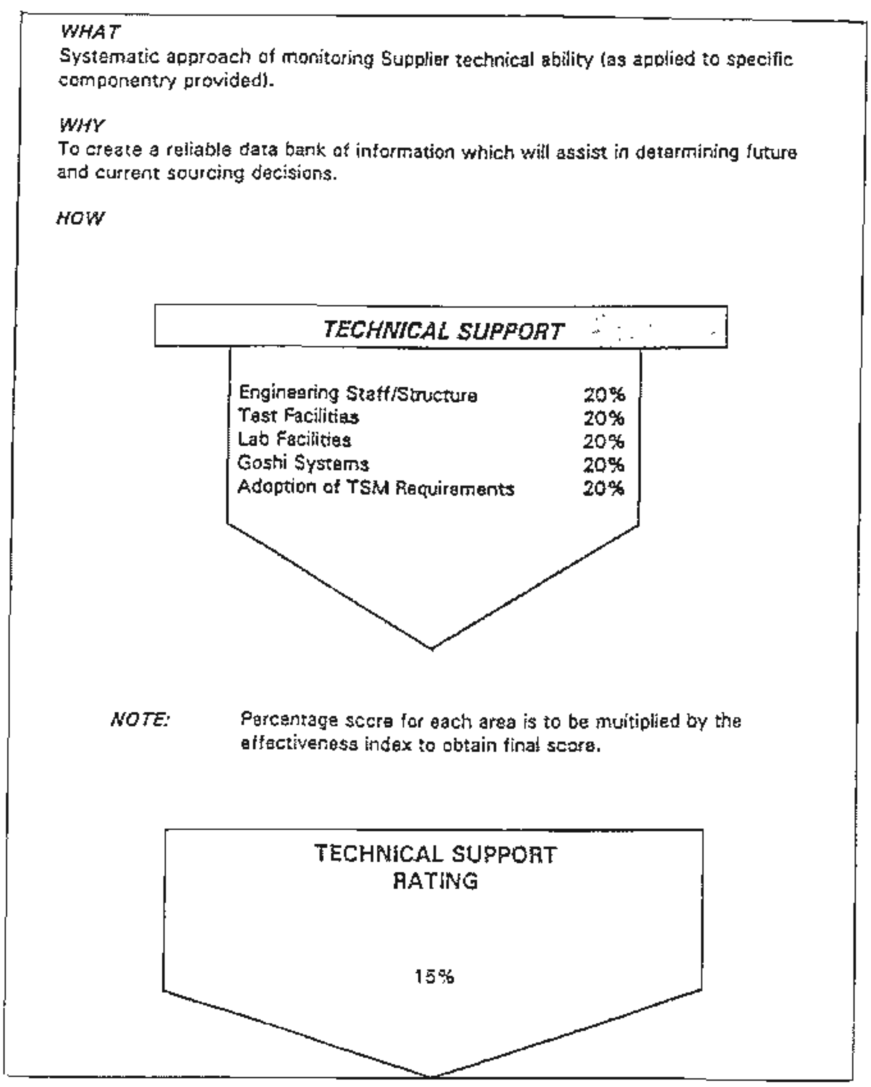


Figure 4.3 Toyota supplier assessment - Technical support

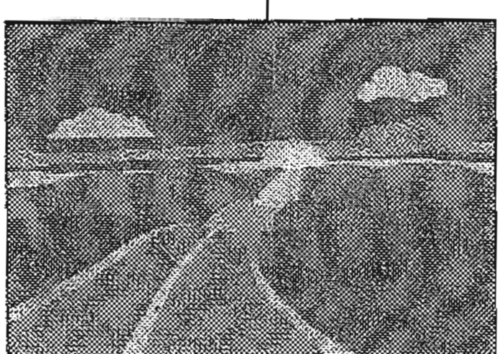


Sub-contracting to small firms

Toyota have initiated a programme designed to increase the level of purchasing from SMMEs. It is designed to generate employment opportunities and lead to the development of new entrepreneurs. The idea has been to identify small entrepreneurs and assist them in becoming suppliers to Toyota. This is being undertaken by a small section (2 people) within the purchasing department. If necessary other departments can be called on to assist with component and production engineering, quality control, material planning, costing and finance procedures. Toyota does not supply direct financial assistance although it will support approaches to banks for loans to purchase tooling etc. SMEs face severe problems in getting a foothold in volume supply to a motor manufacturer. According to Toyota, the areas requiring attention are:

- Product costing - firms are unfamiliar with volume production costing procedures
- Raw material supplies - credit may be needed to finance purchase of raw material
- Production planning - lead time for raw materials and strict delivery requirements
- Production engineering - small firms require assistance with tooling design and production methods suited to volume production and consistent quality
- Financial systems - assistance is required with financial procedures
- Payment has to be on a more frequent basis

This programme is very modest in scope and appears to have met with limited success. Its objective is to increase sourcing from SMMEs from the current R7m per annum which represents only 0.5% of the R1.5 bn which Toyota spends with its 130 South African original equipment suppliers and 800 general goods and services suppliers. The limited success achieved so far has not been in components but in services and peripheral items such as metal pallets, taxi seats, tonneau covers for trucks, cleaning services and security lockers. These are produced by micro enterprises mainly operating out of KwaZulu Finance Corporation small enterprise hives with minimal capital equipment. One of the few black owned component supplier firms is a plastic injection moulding firm being established in Gauteng. A key constraint for OE component supply is that the volumes required are far beyond the capabilities of most black owned small enterprises. Apart from the problems of limited capacity among black firms, a further constraint is the attitude of existing buyers who are reluctant to consider new sources of supply and expect 100% reliability from the outset.



Conclusion

Intensive involvement with suppliers is at an early stage at Toyota and it is too early to make an assessment of the impact. There would appear to be two key constraints on the supplier development process, however. Firstly, the relatively low volumes and wide range of components required by Toyota and other assemblers militate against achievement of world class productivity standards most glaringly in the case of JIT production. Secondly, Toyota's own achievements in terms of work organisation are themselves at a fairly early stage so it may be that Toyota is placing demands on suppliers which it has not itself met and has had difficulty introducing in South Africa's troubled industrial relations milieu.

The determinant factor is likely to be the seriousness of the effort in this direction on the part of Toyota itself. The increased pursuit of world-wide sourcing enables Toyota to place pressure on suppliers as well as to simply import if productivity improvements are not forthcoming. However if the domestic supply base is seriously eroded in the process, the longer term implications for a viable assembly industry will be very negative.

4.3 Alfred Teves Technologies (Ate) - the Problem of Scale

The scale of production is one of the central issues in the South African automotive industry. The cost premium incurred by component makers for producing a wide range of products at low volume is considerable. As is typically the case in the protected Latin American economies, the resulting market structure and pattern of investment has considerable influence on the development of technological capability. The case of Ate illustrates the cost penalties incurred by low volume production and how this has influenced investment patterns and technological effort.

Alfred Teves produces braking systems under licence from Alfred Teves AG which is in turn owned by the giant US component maker ITT. Ate was set up originally for volume production in the early 1980s when the South African market was booming and there was the perception that it would also become a major supply source to Africa. Instead, however, volumes declined and a wider range of vehicles was produced. The firm has been further squeezed in recent years as it lost its export markets when ITT divested and has struggled to compete because of the high costs resulting from short production runs in the domestic market.

The firm is fairly capital intensive and compensation to all employees comprises only 16% of sales. Recent investment has aimed at process improvement but the emphasis will soon fall on capacity expansion. The future of firms such as Ate depend very much on the strategies of local assemblers. The advantages of higher volume production are apparent in the strategy of BMW which is planning to source the right hand drive version of the E46 from South Africa. The firm plans to export 20 000 3 Series vehicles/year from South Africa by the turn of the century.

This will have a major impact on the local component sector as BMW wishes to source 70% of its components domestically and is encouraging its German component suppliers to take equity stakes in South African licensee firms. The price savings that can be achieved from greater economies of scale are considerable. Ate's current production of 15 000 disc brake sets for the 3 series at a cost of R146.00 each is 28% above the price in Germany. If volumes increase to 60 000 vehicle sets it could match the German price.

The major cost savings result from a reduction in fixed costs especially in the amortisation of machinery. These in turn result from reduced machine downtime because of a reduced number of machine changeovers. As the chief executive of Ate puts it:

> "If you want to have a Japanese JIT system and make (a part) when the customer wants it, this would require 280 hours/week (35 part numbers - changeover time of 6-8 hours) just to change over and since a week on a triple shift basis has 168 hours you could not make every part each week so you have to do cost comparisons of how much it costs to change over - make an appropriate quantity for a month (or even 6 months) worth then carry the costs of inventory. The alternative is to put in other machining equipment - so you have six lines but then you have excess capacity".

On the existing line 380 000 pieces (190 000 car sets) can be machined per year at 65% machine efficiency. Change overs also require that before a volume run begins the first off sample is tested for quality. Then production can begin at a rate of one piece per minute. In theory at the end of one shift (480 minutes) 480 parts could be produced. This amounts to five months worth of stock for a low volume vehicle such as the BMW 5 series. So for low volume vehicles, the tendency is to invest in flexible CNC equipment (R1-2m) with a changeover time of 20 minutes. This machinery is highly flexible but very slow with a machining time of 14 minutes per piece (Table 4.2). Dedicated machining lines are designed for speed and comprise a set of eight hydraulically operated fixtures on a rotating table. Eight processes (drilling, milling etc.) are therefore happening

Table 4.2

Flexible machinery vs. dedicated automation

	Flexible CNC machining line	Dedicated automation
Cost	R1-2m	R10m
Changeover time	20 minutes	6-8 hours
Machining time per piece	14 minutes	1 minute

Source: Interviews

simultaneously. With flexible CNC machining equipment each process is separate, accounting for a total of at least 8 minutes plus the time for the machine to replace each tool back in the magazine. Machine changeovers on dedicated equipment are a complicated and arduous task involving removal of the machining table, fixture stations and tools and the disconnection of hydraulic clamping devices. These tasks are carried out by artisans. This type of dedicated machinery is not designed for frequent changeovers and foreign technical experts visiting the plant have been amazed that what they consider to be machine rebuilds are carried out on a routine basis. Frequent changeovers can also lead to quality problems.

Low volumes and the proliferation of models in the domestic market is the major obstacle to improved competitiveness. For example Ate produces 28 different part numbers of brake calliper for total production of 300 000 pieces per year (an average of 10 700 units per part number). The minimum number of changeovers is therefore 28 but in reality would be much higher because otherwise the firm would be holding a year's worth of stock. The decision on how many times to change over depends on the balance of the cost of downtime versus the balance of the cost of inventory. Because of the length of changeovers, low volume parts are only produced once or twice per annum. In contrast, the Ate licensor supplying fist callipers to BMW in Germany produces 425 000 vehicle sets per year of the same part number on dedicated lines out of plants in the UK and Germany. The only changeover required is between left and right which is not as complicated as a changeover between different makes. The diversity of part numbers and the resultant need to queue production means that machine utilisation levels are low, particularly for dedicated machining facilities (table 4.3).

Another problem arising out of such low volume requirements are the huge levels of inventory that have to be carried. Ate has a huge inventory store and stocks of raw material, components, half assembled and completed products are valued at R24million for a firm which has a turnover of R130 m. With higher production levels, raw material subcomponent costs can also be substantially reduced.

Considerable technological effort goes into incremental changes to increase flexibility. To reduce tooling costs for the wide diversity of part numbers produced, a number of innovations have been introduced. For example, broach tools have been divided into segments to make them more versatile. Another large investment is in milling cutters which cost R20 000 each. The numbers of these required have been reduced by putting in special inserts which allow 4 sides of the cutter instead of two to be used. The presetting of tools on CNC equipment has reduced downtime in that area due to machine changeovers. On transfer lines changeover times have been reduced from 16-20 hours to 6-8 hours.

Table 4.3

Comparative Machine Utilisation Rates in a European and a South African Brake Plant

	Europe	South Africa
Dedicated machining	75-80%#	55-60
CNC machining	85%	80

 # 80% can be achieved without machine change overs

Ate's initial investment was in high volume transfer lines which are unsuitable for low volume production runs. Since then the firm has invested in some flexible machinery which minimises machine downtime but cannot compete with dedicated lines where high volumes are required. Many other South African component producers are in an even more intractable situation now that they are confronted with international competition and the need to export. Since the early 1980s a number of component firms (and assemblers) have geared themselves for flexible production and simply lack the output capacity for high volume production. This is a major obstacle for breaking into high volume production for overseas OE markets.

The cost penalties incurred as result of low volumes and complexity in the domestic market are considerable. What is clear, however, is that firms such as Ate have developed considerable production capability in operating complex machinery under very unfavourable conditions, in introducing small innovations to increase flexibility and in the capacity to undertake machine rebuilds to stretch the life of capital equipment. In terms of technological capability, firms like this are a match for many low cost producers internationally although on a simple, price comparison they would be regarded as "uncompetitive". It is therefore important that the process of trade liberalisation takes account of the fact that a significant amount of firm level "inefficiency" may result from the specific industrial structure and also that the nature of fixed investments mean that adjustment to new market conditions cannot be achieved overnight.

4.4 Gabriel : Productivity Gains through Reorganising Production[12]

South African manufacturing firms lag international best practice by a considerable margin and the gap is probably particularly high in the automotive industry which has historically been highly protected. Comparative data on components is sketchy but South African assembly plants have recently been surveyed by the International Motor Vehicle Program (IMVP) and rate very poorly at an average of 89 hours of direct labour per vehicle.[13] The reasons for this include the complexity of the domestic production mix and resultant low volumes, low levels of automation, low skill levels and outdated work organisation. Relatively low wages and high levels of protection have meant that there has, until recently, been little pressure on South African assemblers to seriously address the productivity question. There is widespread awareness of lean production issues but attempts to introduce them have for the most part been piecemeal and of limited effectiveness as evidenced by high levels of strike action and low levels of participation in management initiatives on productivity.

However, the adoption of world class manufacturing methods is likely to accelerate as firms are forced to improve productivity in the face of growing international competition.

[12] This section draws on Black (1994).

[13] This figure is from the preliminary findings of Round Two of the International Motor Vehicle Programme's International Assembly Plant Study by J. MacDuffie and F. Pil at MIT.

In the assembly industry this process may also be assisted by the stabilisation of labour relations following the conclusion of a pathbreaking three year labour agreement in 1995. This agreement which makes provision for higher levels of training, reduced numbers of job grades and reduced differentials between grades is designed to encourage greater co-operation between management and labour in driving through productivity increases.

The component sector also lags international best practice by a considerable margin but there are considerable differences in levels of achievement among firms. One of the most advanced in the area of work organisation is Gabriel, a medium sized producer of shock absorbers, gas and coil springs and MacPherson struts. Over the past several years, it has been engaged in a process of production reorganisation aimed at implementing Japanese style production organisation with a view to increasing productivity and thereby reducing manufacturing costs. As such it provides an interesting and useful case study of this process in the South African context.

The firm is a subsidiary of Maremont which is in turn controlled by Arvin Industries (both of the USA). Arvin Industries controls more than a dozen shock absorber plants around the world in developed and developing countries including the USA, Canada, Spain, India, France, Venezuela and Argentina. These plants which to a certain extent have different capabilities compete with each other for orders all over the world. The principal company has been aggressive in encouraging subsidiaries to reorganise production on a just-in-time basis and provides extensive support for this. Thus all group companies are adopting JIT but are at different levels.

Pressure for change has also come from within the company and management and engineering staff appear fully committed to new production principles. They are fully aware of the need to become internationally competitive in the face of changing market conditions. With the reduction of protection, exports are regarded as the only area of significant market growth. Unusually, the company does not object to reduced protection in the domestic market.

The firm is therefore seeking to expand exports from the current level of 20% of turnover to as much as 50% although 30% is seen as a more realistic medium term objective. It is targeting the foreign aftermarket and its competitive strengths lie in the large range that the company can offer, high quality levels, acceptable prices and small niche market capabilities. Export growth depends on price, quality and delivery times and it is the latter, especially in terms of reliability which presents the main problem.

Production Reorganisation

The major initial innovations in production reorganisation have involved the introduction of JIT manufacturing with a cellular layout, the objective being to "supply only the necessary items at the right time and correct volume to the prescribed quality specifications" (Company manual). This was achieved by introducing the following changes:

* A flow system to move away from large batch production and thereby reduce work in progress.

* Quick change overs. This allowed for greater flexibility through frequent setting up and smaller lot sizes and can be achieved by training, adaptations to tooling and the elimination of set up by trial and error.

* Small lot sizes of 250 to 500 units. Small lots are preferred over continuous runs even if a large quantity of one component is required. The objective is flexibility and better service to the end user.

* Balanced workload with successive work station cycle times to within 5% of one another.

* Effective layout to allow efficient flow of work and "U-shaped" lines to improve proximity of operators to a number of machines.

* Built in quality and in-line checking. Inspection to be performed by operators at point of manufacture. Use of statistical process control (SPC).

* Frequent parts supply with no interruptions.

* Operators or cell leaders to be responsible for basic maintenance.

* Simple visible planning with each cell provided with a daily timetable of units to be produced.

* Continuous improvement achieved by the introduction of action teams (consisting of members of the cell, engineering, maintenance and toolroom personnel) and suggestion schemes.

Implementation

In the initial phase the main feature has been the gradual introduction and ongoing improvement of a number of JIT manufacturing cells. Gabriel were advised by a Japanese consultant to Maremont and the parent company's own JIT co-ordinator who visits Gabriel plants around the world to advise on implementation and to train personnel. In 1989 an implementation team was formed in Gabriel SA consisting of design engineers, toolmakers and maintenance fitters. The first major project was a gas spring assembly cell followed by the establishment of a shock absorber assembly cell for which most of the machines were designed and built in-house. Further cells have since been established. A kanban system has been introduced to address the problem of lead times and levels of work in progress. The company is now close to achieving the world class efficiency targets of the Arvin Total Quality Production System (ATQPS) with progress monitored at a high level of detail (Appendix 3).

Table 4.4:

International productivity comparisons in the Gabriel Group, 1992

	Units/person day (early 1992)	Plant size and product variety compared to the SA plant
India	24	slightly larger plant
Mexico	27-28	slightly larger plant
South Africa	30	largest variety of all plants
Spain	200	large scale producer for OEMs only 400 part numbers
USA	110-180	larger, less variety
Venezuela	41-42	same size, simpler mix

Note: Inter-national differences can be accounted for by a number of factors only some of which are directly the result of firm level productivity (advanced production organisation, automation). Other factors such as product range which impacts negatively on productivity according to the above measure may result from a fragmented domestic market and/or the company targeting the aftermarket which requires greater variety but also has better prices. Thus the Spanish plant is not directly comparable with the other plants as it produces for the original equipment market. But it also operates on a well developed JIT system and is highly automated.

International competitiveness and productivity

Table 4.4 gives an indication of how productivity in the South African plant compared to other plants in the Gabriel group in early 1992, according to the measure of units produced per person/day. At this time the South African plant was not really competitive although its niche market capabilities meant that it did have some export capability. By 1996, productivity had doubled so that the plant was highly competitive. Another measure used was cost of employment as a percentage of sales. This stood at 19% in 1993 (with a target of 15%) compared to the 28% achieved in the US.

The initial productivity improvements resulted in retrenchments rather than a large increase in output or exports. Employment declined from 640 in the late 1980s to 340 by 1993. This included cutting salaried staff from 130 to 70. Employment has since increased to 375 with increased exports and a growing domestic market.

Productivity gains resulting from the introduction of cellular manufacturing were very significant. For example by 1993, the gas spring cell had increased production and flexibility but with a substantially reduced labour force (Table 4.5). Fifty percent of production from this cell was being exported as a direct result of productivity improvements. In the strut cell, five workers (previously nine) were able to maintain production at 1000+ units per shift.

Table: 4.5

Productivity improvement in the new gas spring cell

	Old assembly line	New JIT cell
No. of workers	8	3
Output per shift**	500-1000 units	1000-1500 units
No. of machine changeovers per shift	3-4	7-8

** Shifts were longer on the old assembly line

Source of Productivity Increases

* Machine set up times

This has been a major area of improvement and was the initial focus of the team established to introduce JIT. Set up times used to range from 30-120 minutes. This has been reduced to around 12 minutes in most cases. The world class target is an average of 10 minutes. Under the old system, downtime resulting from lengthy set up times meant that 50-70% of potential production was lost. Reduction in set up times has been achieved in a number of ways. Machine setting was previously performed by a special category of setters while this task is now performed by the operators themselves. Large numbers of adaptations to machinery have been introduced to reduce set up times. Some of these are extremely minor but have nevertheless been effective e.g. fitting clips to machinery which means that Allen keys or spanners are no longer necessary to change settings.

To assist in this process, the company has established a number of small toolmaking companies (consisting of ex-employees) who specialise in making machines more flexible. Most of their work is for Gabriel but they also work for other firms.

* Batch size

Batch sizes have been reduced but this has proved more difficult than reducing set up times. Prior to the reorganisation the minimum batch size was 2000. Average batch sizes are now approximately 200-250 with some batches being as low as 50.

* Stock levels

Prior to the reorganisation, the company used to have eight weeks of finished stock. By 1993 this had been reduced to under three weeks and the aim is seven days. Raw material stock has been hugely reduced through the introduction of a paperless kanban system

Supplier development

Gabriel has over the years developed a close knit network of sub-contractors, most of which consist of ex-employees. Its approach is to focus on key areas of competency and outsource other tasks where possible. With the major improvement in in-plant efficiency, Gabriel now considers the bulk of its problems to be supplier related and is increasingly focusing on developing its supply chain. Targets are being set for suppliers with performance being monitored and rated. Firms which receive a poor C rating are required to make immediate improvements. The number of sub-component suppliers is also being reduced to 20 from 68.

Economies of scale and flexible specialisation

Most component firms consider that wide variety and low volumes place them at a considerable disadvantage both in export markets and competing with imports in the domestic market. In only a few areas have firms been able to establish world scale facilities with relatively high degrees of automation. Thus there is a strongly held view that rationalisation of the number of models and makes would result in greatly improved competitiveness. At the same time it has been argued by some of the more vocal champions of lean production that Japanese style production allows for the efficient production of a large variety of products and reduces minimum efficient scale.

The experience of Gabriel provides some support for both views. Gabriel is a low volume, high variety producer. Production reorganisation has centred around productivity improvement while maintaining this flexible capacity and in fact making a virtue of it. However, even for a firm which has gone a long way towards implementing lean production methods, the fragmentation of the South African market remains a problem. The firm produces in excess of 700 part numbers and has a product range which is higher than any other two companies in the Gabriel group combined. It has to deal, for example, with 17 diameters of piston rod while the maximum in other companies is 7-8. As an extreme contrast, the Spanish plant which operates on a JIT basis has achieved high productivity on the basis of dedicated automation. A Gabriel production manager who visited the Spanish plant reported that one of its automated shock absorber lines had been producing 6000 units per day of the same part number for the past 4 months. The South African operation produces 10 000 units per day including struts and gas springs in a large range of types.

Production reorganisation coupled with limited rationalisation of the product line has dramatically reduced the costs associated with low volume production of a wide range of components to the extent where this is no longer seen to be a key problem.

Process of change and reaction of the union[14]

Workers have reluctantly accepted the changes at Gabriel. While they are fully aware of the need for productivity improvement to maintain the viability of the plant in the face of international competition, the main impact of restructuring has been retrenchment. While the company claims that this is necessary to create the basis for future expansion, the benefits (in terms of new employment) have still to materialise although current jobs appear secure.

As has been the case in other situations in South Africa and elsewhere the union finds it difficult to respond to the negative aspects

[14]. This section is based on an interview with members of the shopstewards committee, conducted in 1993.

(retrenchment) resulting from restructuring. With some success they have tried to ensure that greater efficiencies and cost-cutting also took place in other parts of the firm. Thus the layers of management have been substantially reduced and the number of salaried staff have been cut back in roughly equal proportion to hourly paid workers. The union also fought for and were successful in achieving a reduction in management perks such as company cars.

Workers complain that the intensity of work has increased under the cellular system and coupled with excessive overtime being worked is an important reason for the growth of absenteeism even though a bonus system has been introduced in an effort to limit this. While they accept that training has increased they argue that multiskilling has resulted "in people working harder, not smarter". They have not opposed the introduction of 'green areas' which have been seen in some firms as an attempt to undercut the union. Instead they are seen to have some advantages and clearly serve as a place where union organisational work can also be conducted.

Implications for policy

Gabriel is in many ways a typical South African component company. It produces a vast range of products and historically this has raised costs and limited the scope for further automation. This is a situation faced by many South African component firms. There are two alternative routes available to such companies. One would be to increase specialisation and thereby generate greater economies of scale. This would involve transforming themselves into high volume suppliers with foreign OEMs probably comprising a significant part of their market and would require greater levels of automation. The alternative is the direction that Gabriel has pursued - making a virtue of product variety and increasing its efficiency in flexible production.

The latter course offers a number of advantages from the perspective of the national economy:

- it illustrates the gains that can be made through re-organisation on the shop floor.

- it economises on capital. There has not been a major emphasis on introducing new automation except in a few areas. Investments in capital equipment have primarily been low cost incremental innovations designed to improve the functioning and flexibility of existing machinery rather than adding new equipment.

- it has generated substantial opportunities for learning and indigenous technological adaptation. The company has developed significant toolmaking and machine building capabilities and is thus able to modify its capital equipment and in some cases even build its own machines.

- this form of restructuring may generate significant possibilities for small firms. Gabriel has assisted in establishing small toolmaking firms on a subcontracting basis. This cluster of small firms are engaged mainly in modifying machinery to make it more flexible. This kind of expertise clearly has significant external benefits.

- in an ideal situation, restructuring would enable productivity improvement to be immediately translated into higher total output with unchanged (or even increased) employment levels. This is why the process is always more difficult when markets are stagnating and little new investment is taking place. Under these circumstances it is difficult to generate worker support for these programmes - the more likely scenario being resigned compliance in the face of the alternative being even worse. At the broader industry level, therefore, account needs to be taken of the state of the overall economy in the timing of liberalisation measures which would tend to accelerate the process of plant level restructuring. Phase VI was introduced at the worst possible time in this respect. The first year at least of the MIDP has coincided with a period of expansion in the industry.

5. POLICY CONCLUSIONS

South Africa's automotive component industry has all the characteristics typical of the industrial structure of protected semi-industrial countries described by Katz (1987). The small, protected and fragmented market is a key feature. It affects the type of investment undertaken, the degree of automation, and the nature of learning and R&D activity within firms. It is manifested in low rates of machine utilisation, high levels of inventory and complicated logistics. Another feature of the sector is the high level of vertical integration, a result of poorly developed and high cost supplier networks. The result is a lack of specialisation.

While component producers are heavily reliant on foreign technology and have very limited product development capability, most firms have acquired significant capabilities in undertaking new investments and particularly in process technology. Learning has been significant and is ongoing. However, as was the case in the Katz et al (1987) case studies of protected Latin American manufacturing firms, much of the technological effort and incremental innovation of South African automotive component firms has been directed at dealing with obstacles such as the complexities of low volume, multi-product production rather than simply minimising costs in a mass production environment. As a result, firms have developed certain expertise which may count for little in the international marketplace. For instance, they are flexible but unit production costs are high.

The proposition that the automotive component sector has greater capabilities than is indicated by its level of international competitiveness has important implications for trade strategy. Firms have developed capabilities which could fuel rapid productivity growth if gradually redirected but these accumulated capabilities could also be easily destroyed by rapid liberalisation. So while a more rational industrial structure and higher volumes are prerequisites for cost minimising technological activity, the required changes cannot be achieved overnight because the costs of rapid liberalisation would be catastrophic in terms of the destruction of fixed investments, skills and production capabilities which have taken years to develop. Opening up to international markets is, in fact, already having a significant effect on the industrial structure Larger investments are now required to stay in the game. Firms are being forced to specialise and to move into export markets. Peripheral activities are being outsourced and partnerships with foreign groups are being forged. The rapid expansion of exports is a very positive development because it indicates that firms have the capacity to respond positively to the opportunities offered by a more globalised production environment. One important constraint is in the area of fixed capital particularly where firms have made investments in flexible machinery (e.g. flexible CNC machinery) well suited to the requirements of the previous market structure but more expensive for high volume production.

As the case studies have demonstrated, the development of technological capability is a complex and eclectic process in which formal R&D is one of the less important elements. The accumulation of technological capability occurs as firms make investments and then strive to maximise the efficiency of these investments. South African automotive component firms have developed strong process capabilities but product technology is generally obtained through licence agreements and firms see this as the most cost effective method of acquiring technology. Licensing also brings with it a number of informal mechanisms of technology transfer and important links to the international market place. As a result there is little evidence of a significant shift to local design.

The pressures to undertake technological effort also come from disparate sources. A culture of learning within the organisation appears to be an important factor and this is undoubtedly spurred by greater competition as is now occurring as a result of tariff reductions. However, reduced profit margins may also limit the capacity to invest in productivity raising equipment or organisational change.

International linkages are of the utmost importance as they provide access to markets and technology and cut distribution and marketing costs. Foreign technology transfers are key sources of technological upgrading. They take place through the import of capital equipment, licensing agreements, direct foreign investments, learning through exporting, exchanges of personnel and informal transfers. Exports are a major source of learning because of the demanding nature of the international market place in terms of price, quality and delivery. These links need to be encouraged.

The key to successful adjustment is the effectiveness with which firms are able to adapt already developed capabilities to a production environment which requires higher volumes and lower costs for the global market. To a large extent, the role of sectoral industrial and technology policies is to support this adjustment process; to ensure that the benefits measured in expanding output, investment and exports outweigh the costs. Four areas of policy intervention which would be of specific concern to the automotive industry are outlined below. Clearly too, there is a strong case for improved institutional support and training but this applies equally to other sectors and these issues are not discussed.

Work organisation

There is only fragmentary evidence of how work organisation in the component sector compares internationally. The International Motor Vehicle Programme's preliminary survey of South African assembly plants showed that the industry lagged far behind not only developed countries but also developing countries such as Brazil. It is likely that the same situation prevails in the component sector, a conclusion supported by the author's observations in dozens of component plants visited over the last few years. It is also clear that there is considerable variation between plants. For instance, Gabriel is one of the most advanced South African firms in this area and compares well with plants internationally.

Pressure to undertake these changes is driven in part by increased competition. Sources of this know-how vary. In the case of Gabriel, it came initially from the foreign parent but in a situation where changes were strongly supported by local management. In the case of ADE, specialised consultants played an important role while demanding customers can be important as is the case for suppliers to Toyota.

Work organisation is an important part of technological upgrading and is a critical area for policy intervention. Improved work organisation can raise productivity on an ongoing basis without substantial investment in capital equipment. It is dependent more on training and culture change within the organisation and also has a significant effect on related firms. Most significantly in the case of automotive components, improved work organisation can reduce the costs resulting from proliferation and complexity in the domestic market.

Left to the market, firms would be likely to under-invest in this type of improvement. The information and skills necessary to drive this process are not easily accessible unless firms have close international ties. Most South African component groups are domestically owned while customers (assemblers) have become extremely demanding in terms of price, quality and delivery, it is probably also true that both their motivation and capacity to mentor firms in this regard is limited. The antagonistic relationship between assemblers and suppliers in South Africa is also not helpful and while the Toyota initiative is a positive development, its impact remains to be seen. What is also clear is that assemblers have not been notably successful in introducing these practices into their own plants. While the promotion of improved inter-firm linkages is important (see below), there is a strong case for developing awareness of improved work organisation in the industry and providing institutional support in order to accelerate the introduction of such practices.

Relationships between suppliers and assemblers

Closer co-operation between assemblers and suppliers could play an important role in the successful adjustment of the industry. Assembler firms can provide technical support, advice on implementing improved work organisation as well as access to export markets. The carrot of long term supply contracts and the stick of global sourcing are sufficient incentives for component suppliers to upgrade if the assembler plays an active mentoring role. There may be a role for state or quasi-state agencies to facilitate such a process.

Assemblers have moved slowly to develop more co-operative links with suppliers aimed at upgrading the supply base. The abolition of local content requirements and the ability to rebate import duties means that the easiest short term route for assemblers is simply to import. While there are some indications of assemblers increasing investment in the supply base and encouraging foreign firms to form joint ventures with local companies this is predominantly for a small selected group of suppliers with the main objective being to generate exports. A more common response as tariffs decline is to source product internationally.

The Brazilian example of inter-firm co-operation described by Addis (forthcoming) is highly relevant to the South African situation and is worth recounting in some detail. Under pressure from market liberalisation, assembler firms called in consultants to devise programmes for suppliers. The understanding was that improvements based on measures such as sales per employee, inventory turnover, machine set up times and rejection rates by component suppliers would lead to higher volumes and longer contracts.

Interestingly, smaller suppliers saw opportunities for themselves in this process and engaged the support of a recently privatised small business support service. On the basis that small firms would invest in improvements if they could receive undertakings that they would not be cut out from orders, new quadripartite governance arrangements began to emerge in which:

* large firms undertook to engage all suppliers (including small firms) in longer term contracts in exchange for higher productivity and reduced costs.
* the recently privatised government agency played a key role in negotiating terms with assemblers and also subsidised the cost of consultants to small firms.
* consultants devised programmes suitable for presenting to groups of small firms thereby cutting their costs
* small firms started to work as a group with the consultants, collectively setting goals and measuring progress.

The success of the pilot project has led to variants of this programme being adopted by other suppliers and by firms in other sectors. The long term benefits of greater co-operation are so significant for the South African industry that a strong case could be made for government to facilitate such an arrangement.

Investment Promotion

The promotion of rapid investment into the sector is of key importance and deserving of government support. In this, the investment decisions of the major international vehicle manufacturers are critical. For example, the location of a world scale assembly (or major component plant) plant in South Africa would have enormous spin offs for component producers by creating sufficient demand to enable firms to start achieving the volumes necessary to undertake some domestic design.

Technological support

While most automotive firms are quite advanced at the process level they are generally very reliant on imported design and product technology and there appears little likelihood of this changing. Sources of technological inputs include licensing, direct investment, informal transfers, consultants and domestic and foreign customers. Firms are highly dependent on licensing which involves substantial costs in terms of royalties and constrains firms in export markets. But most firms producing more sophisticated components see licensing as the most cost effective way to access required technology. In the few cases where technological leadership has been achieved, South African firms may lack the resources to sustain this lead and there have been cases of firms regressing towards dependence on licensing in the face of the massive R&D capacity of international groups.

The main forces driving technical change therefore, are cost reduction and exporting. The innovations that are developed are mainly incremental and in the area of process rather than product technology. They result from problem solving in the production area rather than formal R&D. Many result from the effort undertaken to deal with problems of low volume multi product production.

Direct support for R&D would therefore be of little benefit to most firms unless it was linked to a broader (state sponsored) initiative, for example, to develop local expertise and design capability in a major component. ADE is one of the largest component producers but does not even have a formal R&D department even though it has been a rapid learner. Given the disparate nature of technology used in the automotive sector which comprises technologies ranging from plastic injection moulding, foundry technologies to machining, technology centres may have to address the needs of clusters of smaller firms (e.g. stamping firms) rather than components producers in general.

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APPENDICES

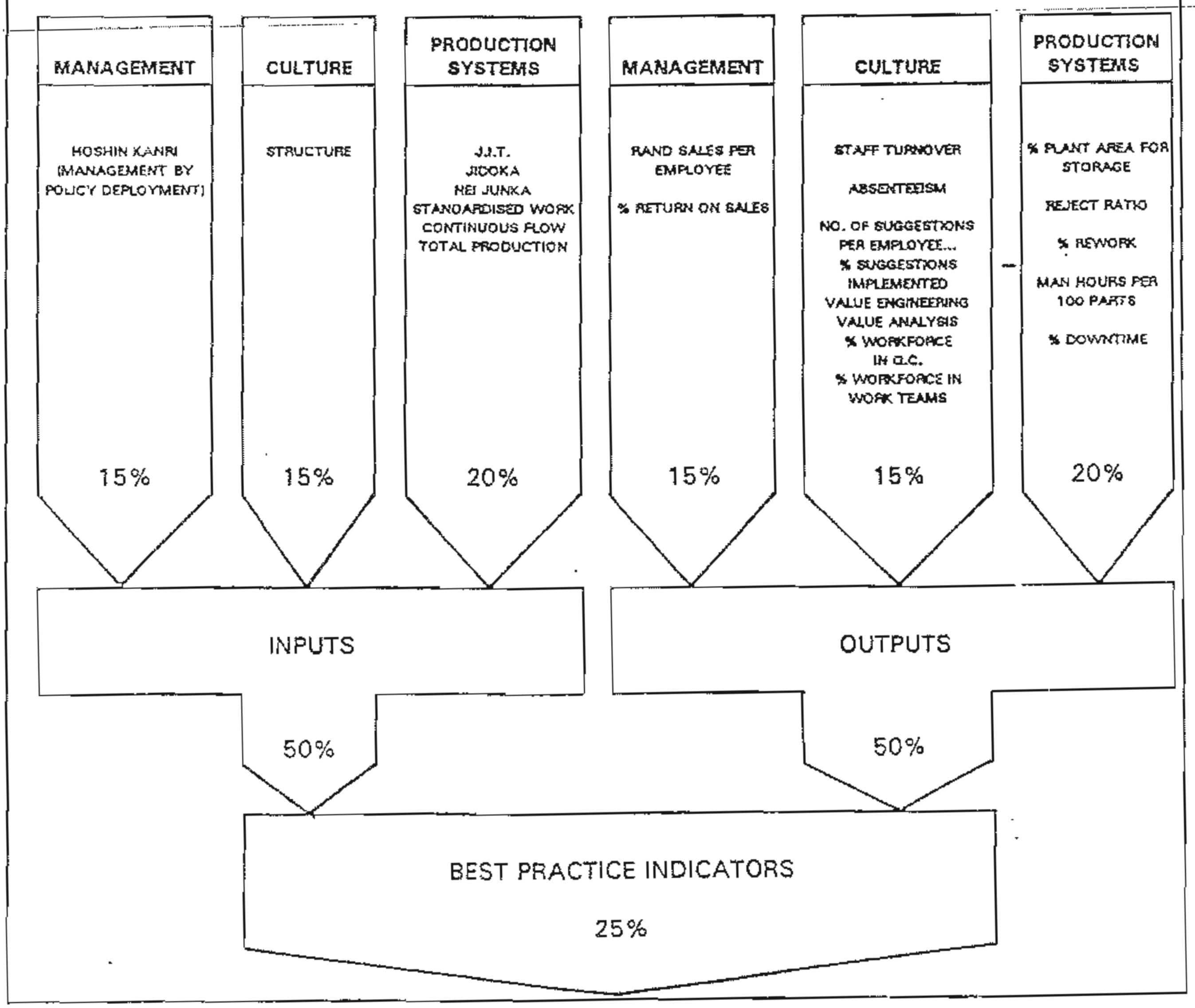
Appendix 1

BEST PRACTICE MANUFACTURING ASSESSMENT

WHAT
A method of assessment of Supplier's internal performance, in the areas of Management, Culture and Production Systems.

WHY
To measure Best Practice Techniques of Suppliers, so as to compare their performance against International Standards.

HOW
Suppliers conducting a self assessment based on the following criteria.
These self assessments are subject to periodic random audits, conducted by Purchasing staff.



Appendix 2

RATING SYSTEM

TERMINOLOGY EXPLANATION

% MIN	% MAX.	SYMBOL	DESCRIPTION	EFFECT ON BUSINESS	ACTION
95%	100%	○	EXCELLENT	PREFERRED SUPPLIER	CONTINUOUS IMPROVEMENT (KAIZEN)
80%	94%	Δ - ○	GOOD	APPROVED SUPPLIER	IMPROVEMENT RECOMMENDED
65%	79%	Δ	SATISFACTORY	RESTRICTED BUSINESS	IMPROVEMENT REQUESTED
50%	64%	X - Δ	UNSATISFACTORY	UNSUITABLE FOR BUSINESS	IMMEDIATE IMPROVEMENT REQUESTED
0%	49%	X	POOR	UNSUITABLE FOR BUSINESS	NOT APPLICABLE

Appendix 3

1996 ATQPS CERTIFIED CELLS MEASURES

CELL: A.M. STRUTS DATE: 29/5/96

MEASURE		INITIAL TARGET	WORLD CLASS TARGET	DATA @ CERT.	FEB	MAR	APR	MAY	ARVIN A's
Suggestions per Employee		2 per employee per month	2	0.52	2	1.4	2	1.5	
% of Suggestions Implemented		75%	85%	62%	92%	42%	100%	77%	
% of Cell Employees on Work Team		100%	100%	100%	100%	100%	100%	100%	A
Training Hours per Person:	YTD(annualized)	40	40	30	11.77	36	48.71	48.10	A
	monthly			N/A	1.96	8	5.61	4.5	
% of Cell Cross-Trained		100% XT set-up & operate 3		12./100%	24./100%	24./100%	26./100%	26./100%	
			100% XT on all machines	12./100%	24./100%	24./100%	26./100%	26./100%	A
Labor as a % of COP		12.0%	10.0%	N/A	4.52%	4.60%	4.20%	5.12%	A
Scrap as a % of COP		2.0%	0.5%	1-2%	0.03%	0.58%	1.12%	0.84%	
Changeover Time	STRUTS	12 minutes	10 minutes	8min	7min 50sec	16min 12sec	16min 4sec	16min 3sec	
Raw Material(Hours)		5 days	4 days	5days	4days	4days	4days	4days	A
WIP(Hours)		4 hours	4hours	4hrs	4hrs	4hrs	3hrs 55min	4hrs	A
Leadtime(minutes)		5 minutes	2 minutes	150sec	14min 5sec	31min 10sec	30min 48sec	30min 41sec	
Process Capability	% Studied	100%		100%	100%	100%	100%	100%	
	% Cpk > 1.33	75%		67%	67%	67%	71%	80%	
	% Studied		100%	100%	100%	100%	100%	100%	A
	% Cpk > 1.67		90% long term capable	50%	58%	58%	61%	68%	
PPM Defective		100	25	N/A	1992	4960	1852	2545	
% Unplanned Downtime		10.0%	5.0%	N/A	19.40%	20.80%	19.26%	21.70%	
Availability		98%	100%	N/A	80.60%	80%	80.74%	77.54%	
Units/Manhour				N/A	9.01	8.7	8.39	7.9	

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