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PRODUCTION COST MODELING FOR THE AUTOMOTIVE INDUSTRY

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ABSTRACT

The automotive sector is widely recognised as one of the industries which greatest importance can assume in the development of a country's economy. This importance was irreversibly recognised by the Portuguese Government in 1963 and since then, the sector has experienced a growth that currently gives it the number two status in terms of national exports. Being relatively recent in Portugal, this industry and the exponential growth it has experienced in the last decades have yet to be fully understood. This thesis aims to contribute positively to increasing the knowledge base of this industry in Portugal by identifying and characterising the main competitive advantages of the Portuguese automotive components industry, more specifically of the stamping subsector.

Notwithstanding the significant development which has characterised the sector, and the stamping companies in particular, core competencies are still generically restricted to manufacturing. As such, this thesis will concentrate on analysing companies from the point of view of their manufacturing competencies and capabilities through the use of technical cost modeling which is specially well adapted to analysing manufacturing processes.

The analysis presented in this thesis points towards two main aspects. The first refers to the positive exploitation by the components suppliers of the Portuguese exogenous factors, the second, the possibility of introducing specific improvements in manufacturing performance which will yield significant cost savings. The identification of these areas of improvement was based on the analysis of the exogenous factor conditions, company and product characteristics, as well as product attributes valued by the clients.

Moreover, these results confirm the usefulness of technical cost modeling as an analysis tool to characterise and evaluate manufacturing processes, identify possible areas of improvement and help define companies' operations strategies and competitive positions. These results are possible when manufacturing data is complemented with market, company-wide and environment information. Although only a reduced number of case studies were undertaken in Portuguese stamping companies, the results obtained in this thesis do not point towards substantial difficulties in applying the same methodology to other companies in this subsector, sector or even to enterprises from other sectors of activities as long as the corresponding technologies are conveniently modelled and the researchers have an adequate understanding of the industry being studied.

Key-words: Competitiveness, Manufacturing Performance, Technical Cost Modeling, Automotive Components, Stamping

RESUMO

A contribuição da indústria automóvel para o desenvolvimento económico de um país é amplamente reconhecida. O Estado Português reconheceu esta importância em 1963, tendo nesse momento o sector iniciado um crescimento que presentemente lhe concede o estatuto de segundo maior exportador nacional. Sendo relativamente recente em Portugal, esta indústria e o crescimento exponencial que tem experimentado estão ainda por ser claramente compreendidos. Face a esta realidade, a presente dissertação visa sobretudo contribuir para o enriquecimento da base de conhecimento relativa a esta indústria em Portugal através da identificação e caracterização das principais vantagens competitivas da indústria de componentes para automóvel, mais especificamente, do subsector de estampagem.

Encontrando-se as competências nucleares das empresas de estampagem centradas na produção, a presente dissertação focaliza a sua análise na vertente das competências e capacidades produtivas das empresas através da utilização de Technical Cost Modeling, ferramenta especialmente vocacionada para a análise de processos produtivos.

A análise apresentada nesta dissertação aponta no sentido de dois aspectos fundamentais. O primeiro, diz respeito à boa exploração, por parte dos fornecedores de componentes nacionais, das condições proporcionadas pela envolvente. O segundo, para a possibilidade de serem introduzidas melhorias especificas em termos de desempenho produtivo que poderão contribuir para significativas reduções de custos. A identificação das áreas onde tais melhorias são possíveis baseia-se, por um lado, na análise dos factores exógenos às empresas, e por outro, nas características das empresas e dos respectivos produtos.

Os resultados confirmam igualmente as vantagens resultantes da utilização da modelação técnica de custos como uma ferramenta de análise que permite caracterizar e avaliar processos produtivos, identificar possíveis áreas a melhorar, bem como contribuir para a definição de estratégias operacionais e posicionamentos competitivos. Tais resultados são possíveis complementando dados produzidos pelos modelos com informação relativa à empresa, ao seu mercado e envolvente. Apesar do número restrito de casos de estudo utilizados, os resultados obtidos não evidenciaram possíveis dificuldades em futuras aplicações desta metodologia a outras empresas do mesmo subsector, sector ou mesmo a empresas de outros sectores, desde que as respectivas tecnologias sejam devidamente modeladas e os investigadores sejam conhecedores das especificidades da indústria em causa.

Palavras Chave: Competitividade, Desempenho Produtivo, Modelação Técnica de Custos, Componentes para Automóvel, Estampagem

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1. OVERVIEW

The automotive sector is widely recognised as one of the industries with greatest importance in the development of a country's economy. This importance was irreversibly recognised by the Portuguese Government in 1963. Since then the sector has experienced a growth that currently gives it the number two status in terms of national exports and a contribution of approximately 7% towards GDP (Veloso *et al.*, 2000). Being relatively recent in Portugal, this industry and the exponential growth it has experienced in the last decades have yet to be fully understood. This thesis aims to contribute towards increasing the knowledge base of the industry in Portugal.

The primary objective of this dissertation is thus to help identify and characterise the main competitive advantages of the Portuguese components industry, more specifically, of the national stamping companies. Although some factors have historically been assumed to be responsible for the significant growth of this sector in the last decades, through a structured analysis of non-aggregated industry data and by focusing on the core technological competencies of companies, this work intends to explore these common assumptions with more detail.

The focus on stamping derives from three separate circumstances, namely, the historical and present importance of this sub-sector within the Portuguese automotive components industry, previous work undertaken by ITEC and INTELI (TEC+ - Technological Audit Programme; Auditec – Technology and Innovation Audit Programme; European Benchmarking Logistic Services – DGIII and DGVIII) with companies whose core competencies are in metal forming, and the possibility of applying technical cost models developed by MIT which model the stamping, assembly and painting technologies. A detailed characterisation of these models can be seen in (German, 1998).

The methodology used in this thesis was partially made possible by the study 'Global Strategies for the Development of the Portuguese Autoparts Industry'. This project, which brought together several MIT research organisations, IAPMEI – Instituto de Apoio às Pequenas e Médias Empresas e ao Investimento, INTELI – Inteligência em Inovação, FEUP – Faculdade de Engenharia da Universidade do Porto, and fourteen Automotive Components Companies, permitted the technology transfer of the stamping Technical Cost Models from MIT to these institutions hereby supplying the work undertaken in this thesis with a structured and flexible tool in the analysis of manufacturing processes.

Three Portuguese automotive components companies are studied in terms of their competitive positioning in the market. The evaluation and characterisation of competitiveness is made in accordance with well-established concepts of firm level competitiveness.

This dissertation has its most significant contribution at the firm level. Besides helping characterise these companies' competitive advantages, it outlines development paths for the companies based on their present characteristics and future industry trends. Since these companies share many common characteristics with other Portuguese firms in the same industry, a careful extrapolation of the results obtained with the three case studies will also provide some insight into the competitive advantages of a larger number of companies operating in this industry.

Notwithstanding the far smaller impact, policy recommendations are equally made, since some of the findings at the firm point towards the significant role of Government in creating the necessary conditions for the future development of this industry in Portugal.

In addition to this overview, the present dissertation includes four other chapters. In Chapter 2 a characterisation of the global and national automotive industry is made. Considering that OEMs are the main players in this industry, and that the future structure of this industry is, to a large degree, determined by these companies, Chapter 2 will start by analysing the main OEM strategies and the resulting industry tendencies. On the other hand, although the case study companies do not supply the industry exclusively as first tier suppliers of original equipment, OEMs represent a large portion of these companies' overall turnover and effectively constitute their main market.

Analysing competitiveness requires identifying competitions and assessing their capabilities. The opening of national economies to international trade and the elimination or reduction of trade barriers, have resulted in growing international competition, and as a result, these companies' competitors are no longer geographically or otherwise readily identified. Besides, the fact that this industry shares a large number of common standards and procedures has led to a convergence of customer expectations and the need for companies to continuously benchmark their performance against that of others. As such, companies are increasingly expected to perform according to best practices regardless of the sub-sector to which they belong. This makes understanding the automotive components industry of the utmost importance. The last part of Chapter 2 is dedicated to the characterisation of the Portuguese automotive and components industries. Since national environments are still largely responsible for defining the competitive advantages of companies, this characterisation is equally essential.

Chapter 3 presents the methodology used in assessing firm level competitiveness. Firstly a model for evaluating competitiveness is defined. This model considers different levels of competitiveness measures, namely, profitability, market share, product attributes, factors defining product attributes and management level indicators. The analysis of the factors defining product attributes and management performance, which is partially based on the use of TCM (Technical Cost Modeling), will be preceded by a description of the main characteristics of this cost modeling technique. Considering that TCM models are custom developed according to the technologies being modelled, a brief description of the model used in the case study analysis is equally presented.

The main results reached in the analysis of firm competitiveness and competitive positioning, and the competitive advantages resulting from the environment in which the companies operate are presented in Chapter 4. In order to put into context some of the results obtained with the analysis, these results are preceded by a general characterisation of the three companies. This is done without resorting to a structured methodology but instead by focusing on the past and present characteristics of the firms that are essential to our understanding of their reality.

Finally, Chapter 5 presents the main conclusions of the dissertation and puts forth a set of recommendations aimed, not only, at the companies studied and the Portuguese components industry as a whole, but equally, at the public entities that are responsible for creating and maintaining an environment that is favourable to the present and future activities developed by this industry in Portugal.

2. GENERAL CHARACTERISATION OF THE AUTOMOTIVE INDUSTRY

2.1 CHARACTERISATION OF THE GLOBAL AUTOMOTIVE INDUSTRY

The automotive industry has been one of the fastest growing industries in the world. This growth is expected to continue albeit in a context of an estimated 40% overcapacity of world production. Simultaneously, excess production is by no means new to this sector of activity. In fact, since the 1st World War, and with the exception of the 2nd World War period, this industry has been producing more cars than it could sell. Table 1 permits a combined analysis of vehicle production and sales in recent years where we can clearly see that excess capacity has been gaining ground – in 1998 the number of vehicles assembled exceeded the number of registrations of new vehicles in approximately 17.4 million which corresponds to 32% of world production.

Table 1 - World-Wide Vehicle Production

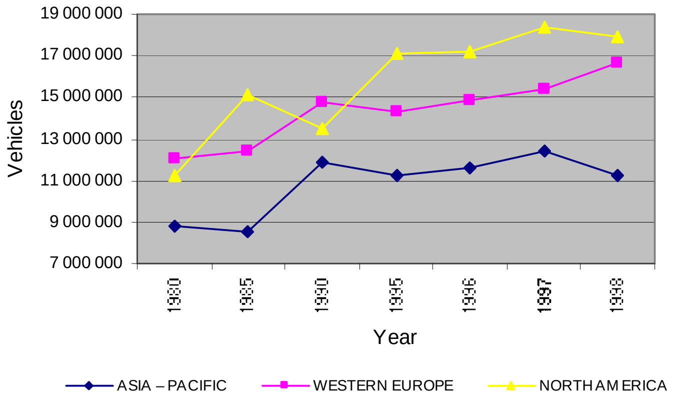
	1980	1985	1990	1995	1996	1997	1998
Commercial Vehicles	**9 675 970**	**12 661 000**	**12 399 000**	**14 797 589**	**15 462 000**	**15 981 000**	**15 062 000**
Passenger Vehicles	**29 720 637**	**32 601 372**	**35 802 207**	**35 635 641**	**36 485 000**	**38 453 000**	**37 925 000**
Total	**39 396 607**	**45 262 372**	**48 201 207**	**50 433 230**	**51 947 000**	**54 434 000**	**52 987 000**

Source: CCFA

One of the main contributing factors have been the "build-where-you-sell" OEM strategies which have increased capacity in new markets without eliminating pre-existing capacity in others. Moreover, some past expansion decisions have not been based on realistic market opportunities. Sooner or later the issues of overcapacity and excess production will have to be tackled by the automakers, since they are currently responsible for eroding an important slice of their profit margin.

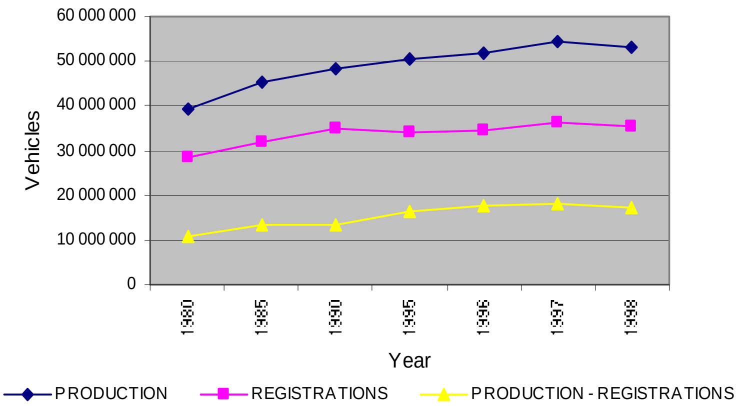
The solution to this issue will probably be possible only when OEMs move to smaller, more flexible assembly lines, capable of producing a greater variety of models in closer accordance with regional demand. Nevertheless, at the moment, this issue does not rank very high on OEMs' priority list as can be seen in Figure 1, Figure 2 and Figure 3 where we can see that overcapacity and excesses production has not inhibited the growth in production in most regions of the globe.

Figure 1 - Vehicle Production by Region



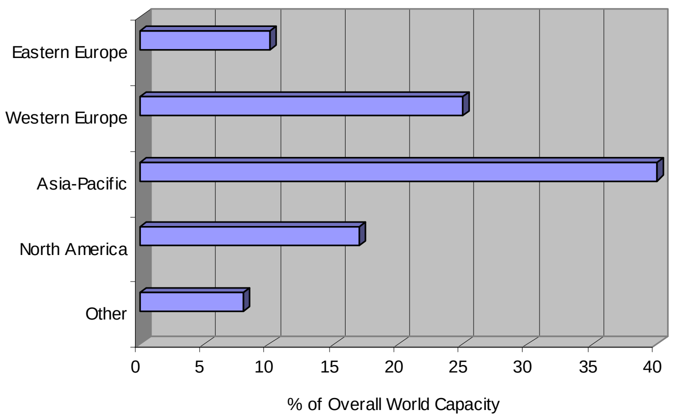
Source: CCFA – Comité des Constructeurs Français d'Automobliles

Figure 2 - Excess Production



Source: CCFA

Figure 3 - Overcapacity



Source: Autofacts Inc.

Figure 1 shows a steady increase in the number of vehicles assembled in the three main automotive industry regions of the world, namely, North America (USA, Mexico and Canada), Asia-Pacific and Western Europe. As for the Asia-Pacific region, the intense crisis which has marked the economy of many important vehicle-producing countries during the last years, is undoubtedly responsible for the decline in the number of vehicles produced in this part of the globe during the last years under analysis.

Overcapacity has thus had a somewhat restraining effect on growth, that is, growth is mild in regions with significant overcapacity and is sky rocketing in regions where overcapacity assumes less importance (e.g. North America with a 220% increase in production between 1980 to 1998, which can partially be attributed to the Japanese transplants).

Nevertheless, other issues assume significant relevance in today's industry. We will now discuss some of these issues, and whenever possible, analyse the foreseeable implications on the supply structure.

Concentration and Globalisation

The wave of mergers and acquisitions that has swept the automotive industry will probably continue during the next years but at a slower pace. Underlying the repositioning of the OEMs is the realisation that important gains can be achieved from the exploitation of synergies resulting from overlapping or complementary activities. The clearest gains are undoubtedly in joint purchasing and component sharing between merged OEMs.

Analysts' anticipate that, within 5 to 10 years, fewer then seven automaker enterprises, operating with something close to a global scale - a minimum 10% share in a region -, will dominate the industry (PricewaterhouseCoopers, 2000). These companies will have annual vehicle production volumes of more than five million (Mendonça, 1999). Currently, only General Motors and Ford exceed this value, although the Volkswagen, Toyota and Renault/Nissan groups are close to reaching the 5 million mark. Besides the seven OEMs, a reduced number of small independent niche oriented automakers will equally remain in business.

In previous mergers, market overlap has generally been avoided and the different brands existing within the groups have been maintained. In a period when differences between distinct models within the same group are progressively being eroded, brands are progressively the principal distinguishing factor between vehicles.

While the reasons underlying merger and acquisition decisions may vary among OEMs, generically, the use of common platforms, motors and assembly lines, and the benefits in terms of supply chain management have usually been decisive.

This concentration and the move by some automakers towards world car programmes will have significant repercussions on the relationship with suppliers. Once again, capacity may be the main issue that suppliers will have to deal with if they want to maintain a first tier position. In fact, since most mergers are partially based on exploiting the cost benefits of using the same components in different models and brands, suppliers may have to boost production capacity in order to supply a group as opposed to supplying a single OEM. Secondly, suppliers are increasingly expected to accompany OEMs irrespective of assembly plant location and, as such, investments have to be made in creating capacity where it is needed, that is, near the assembly plant. Suppliers have met this challenge by establishing joint ventures and acquiring foreign firms in the countries where OEMs have manufacturing facilities.

Standardisation

The primary objective underlying standardisation is the reduction in product and process development costs. The use of common platforms is perhaps the most significant step taken in this direction, since it has far reaching implications in terms of the design of other parts of the vehicle. In Western Europe, the number of mainstream light vehicle platforms, used by the major manufacturers, is expected to fall from approximately 67 in 1998 to 52 in 2005 (Auto Business Ltd, 2000). Although it has its limitations, this solution permits the construction of a variety of vehicles which can differ quite significantly from each other. As an example, we can mention the VW group, with its VW, Audi, SEAT and Skoda brands which has now reduced the group's platforms to four. Nevertheless, cost reduction through the use of common platforms faces a set of limitations related to the similitude in vehicles. A similar strategy will thus be unfeasible in the Daimler-Chrysler group because of the radical differences imposed by front and rear wheel transmissions. On the other hand, the 500 000 production volume barrier is widely accepted as the profit breakeven point for using common platforms, making this strategy quite selective in terms of the OEMs that can follow it (Mendonça, 1999).

Thus, in certain cases this solution can lead to important reductions in development costs, while simultaneously guaranteeing that vehicles commercialised within the same group do not compete for the same market. This is made possible by, for example, incorporating different suspensions, interior and exterior trim, and vehicle design.

From the suppliers' point of view, increased pressure will be put on production capacity, since OEMs, almost certainly will not increase the number of suppliers of a specific component but will probably maintain or decrease the number of first tier suppliers. Whereas for the larger suppliers this may mean greater levels of specialisation, in the case of smaller suppliers that wish to maintain a first tier position, the answer may be in increasing overall production capacity.

First Tier Supplier Reduction

OEMs are decidedly perusing strategies of concentration on a limited number of high value added activities and outsourcing non-core, lower value work. While in the distant future it is possible to imagine OEMs outsourcing vehicle assembly, the changes in the following years will probably be less drastic. Nevertheless, many OEMs have suggested future specialisation in the areas of vehicle design, final assembly, marketing and sales. The overall result will undoubtedly be higher levels of outsourcing by OEMs and the corresponding transference of responsibilities to the suppliers. This new equilibrium point can only be struck if the number of first tier suppliers with whom OEMs interact is substantially smaller than it is today.

Simultaneously, the reduction in the number of suppliers has clear cost benefits from the OEMs' point of view in terms of purchasing efficiency and supply-base management since OEMs are currently pursuing a 1+1 supply structure, that is, having a global supplier, capable of accompanying them wherever assembly plants are established, and a smaller local supplier whose main role is to compensate any disruption in supply by the global player.

The reduction in the number of first tier suppliers will bring about alterations in the supply structure similar to that described in the case of standardisation, namely, the progressive growth of first tier suppliers, a closer relationship between OEM and first tier supply, an upstream transference of responsibility and an increase in demand on supplier design and development capabilities.

Technological Developments

The many positive repercussions the growth of the automotive industry has had over the years on society are increasingly being offset by the negative environmental impact of vehicle production, use, and disposal. This has forced OEMs to rethink the environmental impact of their products and has led to the increasing use of Lifecycle Analysis (LCA) as an impact assessment tool.

A recent life cycle inventory study undertaken by three representatives from the United States Council for Automotive Research (USCAR) - an umbrella organization of DaimlerChrysler, Ford, and General Motors -, the Aluminium Association, the America Iron and Steel Institute (AISI), and the American Plastics Council (APC) reached the following results:

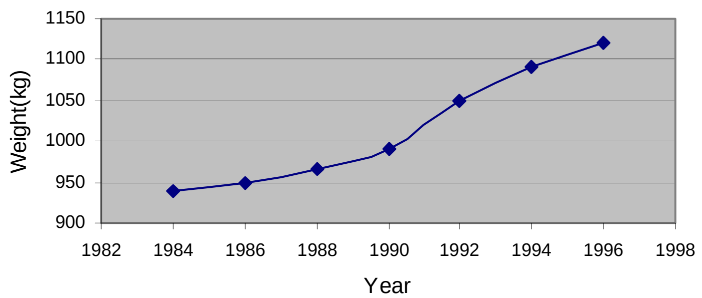
- The generic vehicle's "use" phase dominates energy consumption.
- The material production and manufacturing phases contribute 13% of the energy consumed, 65% of the particulate emissions, 68% of the solid waste, and 90% of the metal waste to water.
- The end-of-life phase contributes with 7% of the total life cycle solid waste, primarily as automotive shredder residue.

The direct impact on the quality of life in metropolitan areas and research that suggest that demand will outpace oil production between 2007 and 2014 have brought into sharp focus the fuel inefficiency of cars. The California Air Resources Board (CARB) and Corporate Average Fuel Economy (CAFE) regulations are good examples of emissions legislation becoming increasingly restrictive. In Europe, general perception is that in the near future, 2 to 3l/100km cars will be the norm. As a result of these pressures, vehicle manufacturers and their suppliers have been taking a closer look at possible ways to decrease the level of air pollution generated by cars.

Besides efforts made in the research of alternative fuels and propulsion technologies, automakers have equally focused on weight reduction and internal combustion engine (ICE) efficiency improvements. Although very positive results have been reached in the development of new propulsion systems, there is still some way to go before the ICE loses its status as the principle propulsion technology, since commercially viable alternatives, namely the fuel cell and hybrid propulsion, are approximately 10 years away. We will thus continue to witness improvements, in the use of the ICE technology, materialised in the reduction of emissions and the increase of engine efficiency. Since the foreseeable developments in the ICE will not significantly impact the Portuguese component suppliers, special focus will only be given to future developments in terms of weight reduction and recycling.

Regulatory and consumer pressure, which became more acute after the 1973 oil crisis, forced OEMs to rethink their offer in terms of economic and medium segment vehicles, till then largely overshadowed by the upper segments in most industrialised countries. As a result, greater emphasis was given to the conception of smaller, more economic cars that were simultaneously appealing to consumers. Present estimates point to reductions of more than half the vehicle weight to meet the above mentioned target of 2/3l/km.

Figure 4 - Weight Evolution of Medium European Vehicle from 1984 to 1996



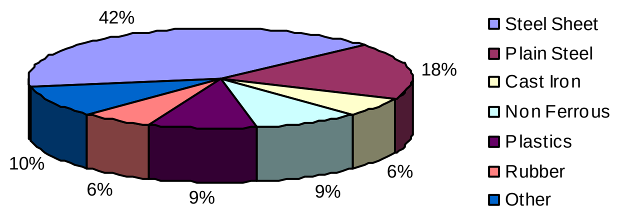
Source: CCFA; MAVEL

From the analysis of the above figure it is apparent that the industry is currently still moving in the opposite direction with an average annual vehicle weight increase of 2% over the last 12 years. This increase has to do with the growing amount of performance, active and passive safety features, and high-tech solutions that are made available to the consumer for improving his or her driving experience. Simultaneously, important weight reductions have been achieved in other parts of the vehicle such as in body and chassis components.

So far, weight reduction has partially been accomplished through the use of lighter materials such as plastics that substituted heavier and sometimes costlier materials like steel and wood, but also through the implementation of different geometrical solutions that did not reduce the system's critical performance characteristics while using the same type of material.

A good example are plastics, which besides the obvious factor associated to its cheaper cost, also present possible gains in terms of strength, weight reduction and design possibilities. The following figure represents the material content of a medium sized European vehicle.

Figure 5 - Materials Content for a Medium European Vehicle (1996)



Source: MAVEL

The shift from steel to polymers directly impacts the injection moulders and the metal processing companies in opposite ways. The steel processing companies will increasingly be forced to incorporate new knowledge relative to the processing of a greater variety of metals, as steel is increasingly substituted for other metals. From the injection moulders point of view, the surge in the use of polymers in the automotive industry is undoubtedly positive. Here the difference will lie in the capability to conjugate different polymers in a single product and to join polymers to materials such as metals. Nevertheless, the increase in polymer utilisation will be limited by difficulties encountered in recycling these materials and, as such, aluminium and magnesium will probably gain ground as lighter recyclable materials.

Since the use of these metals is presently quite restricted to vehicles of the upper segments of the market, a transitional solution may be to use high and ultra strength steels as well as tailored blanks and steel sandwich. Further improvements can be achieved through the use of such manufacturing technologies as tubular and sheet hydroforming, and laser welding that will increasingly be used in metal processing. Combined, they will yield weight savings and improved performance.

The increasing pressures on weight reduction and performance improvement imply that the overall cost of a vehicle be looked upon in a substantially different way. Since these two sets of attributes, may in the short-term, only be attained through the use of costlier materials, added focus must be given to reducing manufacturing costs. This view collides with the current and well established philosophy of mass production based on the use of cheap materials and expensive tooling, by presenting solutions that improve overall performance through the use of more complex and costly materials but which yield substantially smaller tooling costs.

In this context, steel sandwich panel technology has great potential, namely in terms of its use in the production of chassis. This technology, which has been in use in the marine, aerospace and performance vehicle industry for several decades, relies on the physical properties of the stiff, strong outer skin bonded on either side by a thick, lightweight core. Skins are normally made of carbon, aluminium or aramid fibre-reinforced polymer, while the core materials have been constituted by balsa, polymer foams, metallic or polymer honeycombs. Since bending loads are carried by the external elements, significant gains in structural efficiency can be attained by enlarging the distance between the panels while only slightly increasing weight.

Despite the efforts made by steelmakers in offering a greater diversity of competitive solutions, efforts of which the ULSAB is a good example, the significant amount of steel used in cars in the past partially explains the downward trend of the use of this material. Table 2 summarises the expected evolutions in terms of materials used in automotive production.

Table 2 - Prospects in the use of different Materials in the Automotive Industry

Material	Contribution to Overall Weight	Present Drawbacks
Steel	Decrease	Weight
Plastic	Increase	Heat resistance, Recycling
Aluminium	Increase	Price fluctuations
Magnesium	Increase	Price

Source: ULSAB

On the other hand, according to the United States Council for Automotive Recycling, ten million vehicles are scrapped annually in the USA. With a current recycling rate of approximately tree-quarters of a typical vehicle, cars are among the commodities with higher recycling rates.

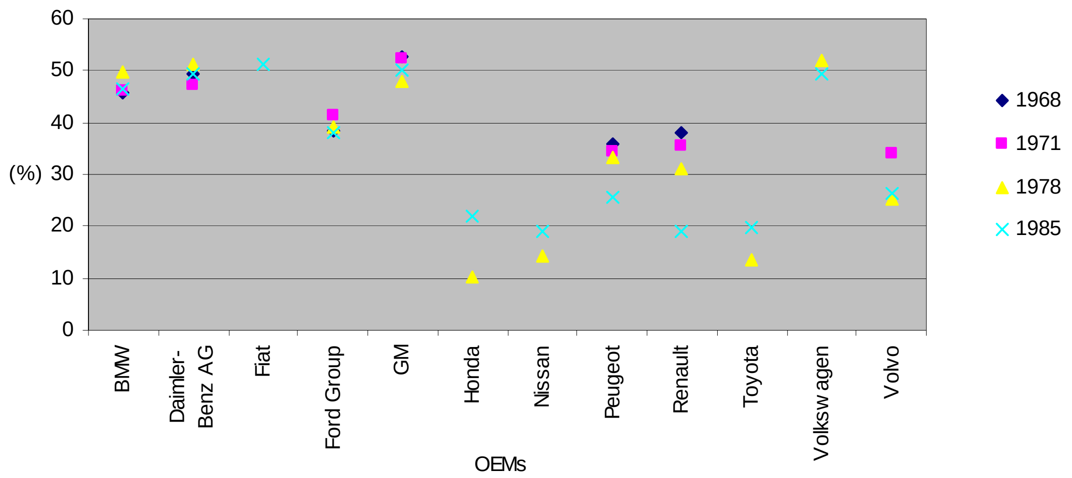
Besides efforts made in the development of processes that seek to reclaim the economic value associated to certain parts of the vehicle through recycling, special emphasis is equally being given to increasing the use of recyclable materials in vehicle production. Notwithstanding some present difficulties associated to the recycling of certain polymers, future product, and manufacturing and recycling process developments will lead to the increasing use of these materials as a means of reducing the impact of end-of-life vehicles on the environment.

2.1.1 Characterisation of the Global Components Industry

The competencies and resources involved in the design, manufacture, and assembly of approximately ten thousand different parts which currently constitute a vehicle and the amount of information used and generated by these processes have made the management of this complexity by a single company virtually an impossible task. In fact, except for the period during which Ford and the Model T dominated world production through the use of single product specialisation and mass production, hereby significantly reducing the levels of complexity of products and processes but simultaneously facing difficulties arising from supplier incapacity to respond to the desired production volumes, OEMs have relied heavily on suppliers. In the years that followed, competing strategies by other OEMs, namely GM, based on product diversification, emphasised the need for more value to be outsourced which further increased the importance of the components industry. Mass production, which by then had been adopted by most OEMs, could finally be based on outsourcing a significant number of parts produced by suppliers under the same mass production philosophy.

Only approximately 15% of total manufacturing processes correspond to final assembly which illustrates the significance the upstream value chain has assumed (Womack, 1991). As can be seen in Figure 6 the Japanese OEMs outsource more of the total value of the automobile when compared to their European and American counterparts. The unique relationship between the Japanese OEMs and their suppliers is commonly linked to this singular reality. Among the Europeans, the German OEMs and FIAT are clearly outsourcing less value than their French and Scandinavian counterparts (here represented by Volvo). When analysing the trend in in-house production during the period under analysis we can identify two distinct tendencies in Europe and the US, and in Japan. The low rates of in-house production registered in Japan grew during the seven years between 1978 and 1985, while the American and European rates showed a tendency to stabilise. More recently, modularisation and supplier reduction programmes have led to even higher levels of outsourcing by OEM.

Figure 6 – In-house Production by OEMs (%)



Source: (Banville and Chanaron, 1991); (Chanaron, 1995)

This situation has led to the growth in number and size of the suppliers which, in turn, has led to the larger components companies rivalling in size with the smaller OEMs as can be seen by comparing OEM and components manufacturers' turnover levels presenting in Table 3 and Table 4.

Table 3 - Major European Manufacturers' Turnover in 1997

Company	Turnover
BMW Group	30 446
BMW Automobiles (excluding Rover)	16 856
Fiat Auto	25 976
Ford of Europe	21 294
GM Europe	22 119
Mercedes-Benz	27 286
PSA Automotive	26 076
Renault (car division)	25 032
Rover	9 875
Volvo Group	10 930
Volkswagen Group, Europe	54 227
Volkswagen cars & commercial vehicles	34 218
Audi	11 347
SEAT	6 051
Skoda	2 613

Source: Economist Intelligence Unit *Values in Millions of Dollars*

Table 4 - Major European Components Manufacturers' Turnover in 1997

Company	Country of Origin	Automotive Sales	% of Total Sales
Bosch	Germany	16 067	61
Michelin	France	13 104	98
LucasVarity	UK	6 735	88
Valeo	France	5 700	100
Continental	Germany	5 393	86
Mannesmann	Germany	4 654	21
ZF	Germany	3 904	78
Magneti Marelli	Italy	3 713	98
GKN	UK	3 422	61
Autoliv	Sweden	3 257	100
Pirelli	Italy	3 084	48
Siemens	Germany	2 528	4
BTR	UK	2 216	18
Pilkington	UK	2 208	46
Krupp Hoesch	Germany	1 854	12

Source: Economist Intelligence Unit estimates *Values in Millions of Dollars*

Estimates on the total number of companies producing automotive parts vary substantially among sources. A study commissioned by the European Community and undertaken by the Boston Consulting Group/PRS (1990) identified approximately 3250 such companies in the EU. On the other hand, Sleigh (1991) identified 1500 enterprises producing automotive parts. This discrepancy is probably the result of difficulties in assessing what in fact is an automotive industry supplier in a context of marginal and fluctuating turnovers in the automotive sector by some of these enterprises.

If we consider the overall activity of, for example the German Bosch or Siemens Groups with total 1997 sales of 26 290 and 60 073 million dollars respectively, then we can fully understand the size and negotiating power OEMs are presently confronted with in their suppliers. The on-going processes of concentration and centralisation, that is, the consolidation of the position of a reduced number of major suppliers and the expansion into the sector by companies considered specialists in other fields of activity, will further contribute to the growth in size of the larger suppliers.

Of the above listed European companies, only two supply the automotive industry on an exclusive basis. Maintaining substantial levels of activity in other industries has been a strategy followed by most suppliers as a form of managing the cyclical trends in the automotive industry. Already in 1991, suppliers such as the British company Lucas, which at that time had 56% of its sales in the automotive industry, looked towards shifting more business into other areas as one of the company's medium-term objectives.

Besides its positive effects on negotiating power, size assumes great importance in part because it permits a level of R&D investment that is compatible with the company's specific tier positioning. Industry sources currently suggest appropriate expenditure rates in R&D of around 5% for first tier suppliers but in 1996 less than half of the biggest companies surveyed in an Economist Intelligence Unit study were actually in conformance with this criteria. The same study equally concluded that the level of R&D expenditure varies in accordance to the nature of the company's products, that is, the companies which engage in research in state-of-the-art technologies are likely to spend a larger share on R&D.

Simultaneously, efforts undertaken by OEMs to improve efficiency in purchasing and supply chain management, are resulting in the reduction of the supply base and in an increase in the complexity of the products supplied at all tier levels. Besides issues related to production capacity (or in other words size), other issues such as R&D investment will probably determine whether a company has the necessary competencies to design, produce, and ship a part that may differ significantly from former company supplies. This will force some of the smaller companies, who wish to maintain their tier positioning, to grow through mergers and acquisitions, hereby increasing not only their production capacity but attaining the competencies necessary for a higher added value supply.

While, in most countries this has proven to be a feasible solution – the wave of mergers and acquisitions which has swept practically the entire globe is widely known -, cultural differences may lead to diverse approaches to this issue in countries where, for a variety of reasons, the full impact of this wave has not yet been felt.

So far, mergers and acquisitions have dominated over joint ventures due to the fact that acquisitions constitute a faster way of attaining the objectives underlying the these strategies. The main reason has to do with not having to blend different company strategies into a single strategy. Instead, the acquiring firm's objectives and strategies dominate the overall objectives and strategies of the new company. On the other, the growth made possible through mergers and acquisitions clearly surpasses growth based on the development of internal resources. In an environment characterised by OEMs demanding constant reduction in unit costs, systems design and production capabilities and global reach, internal growth is just too time demanding. Table 5 illustrates the importance mergers and acquisitions have assumed in the growth strategies of the 25 largest components suppliers.

Table 5 - - Acquisitions in the Automotive Components Industry (1992 – 1997)

Size and Number of Acquisitions		
> $ 600 Million	$ 100 Million – $ 600 Million	< $ 100 Million
Dana (23)	Federal-Mogul (8)	Valeo (11)
Echlin (15)	Borg-Warner Automotive (4)	MascoTech (5)
Magna (17)	Collins & Aikman (4)	Arvin (5)
Johnson Controls (12)	Sommer Allibert (3)	Magneti Marelli (3)
Autoliv (11)	Intermet (2)	Plastic Omnium (3)
BREED Technologies (11)	Excel Industries (1)	Budd (2)
Eaton (11)		ECIA (1)
LucasVarity (10)		Donnelly (1)
Lear (9)		
GKN (7)		
Tower Automotive (7)		
Bosch (2)		

Source: Andersen Consulting

2.2 THE PORTUGUESE AUTOMOTIVE INDUSTRY

2.2.1 Historical Perspective of the Portuguese Automotive Industry

Recognising the importance that the automotive industry can assume in the development of a country's economy and the relative weak stage of development of this national industry, in 1963 the Portuguese government issued a decree that blocked the import of Completely Built Up (CBU) vehicles. The same decree imposed a 25% limit as the minimum national value added in vehicles assembled locally. As a direct consequence of this decision, the automakers that sought to continue to sell cars in Portugal were forced to establish assembly plants within national territory. By 1973, 30 assembly lines were producing passenger and commercial vehicles in Portugal.

Due to the small size of the national market, these assembly lines were of a reduced scale, and consequently inefficient (Veloso and Felizardo, 1998). On the other hand, this production level was by no means beneficial from the Portuguese suppliers' point of view, making it very difficult for these companies to work exclusively for the auto industry on a profitable basis. Only the few that exhibited an organisational structure that permitted the commercialisation in foreign markets, where the necessary scale economies were attained, were able to produce higher value added components. The remaining companies were limited to the production of low value added components, namely small stamped parts. The crises that succeeded the 1974 revolution further complicated the situation of an already fragile industry.

By 1980, international trade agreements signed by Portugal and the realisation that the 1963 policy was no longer adequately responding to national interest, spurred the Portuguese government to outline a new policy. With the new policy, restrictions on the import of completely built up vehicles were attenuated as the import of CBU and Complete Knock Down (CKD) vehicles was now possible if compensated through the export of locally produced components. Simultaneously Foreign Direct Investment (FDI) was stimulated through the use of incentives which partially financed the investments made by foreign companies in Portugal. As a result of this new policy, the smaller companies with inefficient production structures and limited presence in foreign markets faced increasing pressures while bigger companies with an European presence were prospering.

During this period, the Renault project with its engine, gearbox and car assembly factories was not only the most significant in terms of volume of investment but also in terms of the repercussion on the automotive sector. At the supplier level, Renault's presence played an important part in the development of this industry due to the positive synergies that resulted from a geographical proximity to a large OEM. The relevance of this investment can be seen, not only by the number of years of production which amounted to 18 (from 1980 to 1998) but also by the five different Renault models produced at the Setúbal plant during this period.

An important part of the new policy aimed at promoting the export of automotive components and simultaneously boosting national production so as to correspond to the expectations underlying the Renault project, that is, that Portuguese firms occupy a significant part of the Renault supply chain. As a consequence of this policy from 1980 to 1983 approximately 10 billion PTE were invested in this sector in Portugal.

During 1988, all remaining restrictions on EEC imports were lifted and the PEDIP (Programa para o Desenvolvimento da Indústria Portuguesa) programme – aimed at accelerating the development process of the Portuguese Industrial fabric – started. Besides other measures, this programme included, export promotion and the support of already established companies and to foreign companies wishing to establish themselves in Portugal. Within this context, the installation of another large OEM in Portugal assumes great strategic importance for the development of the components industry and national industry as a whole. As such, by 1995, and after intense negotiations with the Portuguese Government, the AutoEuropa Ford/Volkswagen joint venture begins production of Multi Purpose Vehicles (MPV) for the Volkswagen and Ford groups in Palmela.

Besides presenting a reasonable number of favourable conditions, the significant amount of incentives given by the Government, undoubtedly played an important role in the final decision of the two OEMs to install the assembly line in Portugal. In fact, the AutoEuropa joint venture received a total of PTE 158 000 million of incentives in an overall investment of PTE 453000 million. Incentives for the construction of port, rail and road infrastructures amounted to another PTE 14 000 million (Vale, 1999).

Simultaneously, the AutoEuropa joint venture was responsible for a great deal of FDI since some foreign components suppliers followed the two OEMs to Portugal and just in the Palmela region 22 new production facilities were created. Of these, only ten do not correspond to joint ventures with Portuguese companies which is quite demonstrative of the level of development already attained by these companies. Nevertheless, because the agreement between the Ford/Volkswagen joint venture and the Portuguese State placed restrictions on non-national value added, there was an extra incentive for the establishment of these partnerships.

By 1996 the AutoEuropa assembly line was responsible for approximately 82% of all passenger cars produced nationally. This value further increases in 1998 when, after long negotiations with the Portuguese Government, the last Renault Clio is produced in July of that year at the Setúbal plant.

Notwithstanding the plant's closure, Renault's presence was of great importance to this industry, not only from the point of view of the national suppliers but also due to the pool of knowledge and automobile industry culture the project left behind. Indeed, many of the intermediate and higher level Renault staff which are now working in major national components companies are transmitting to these enterprises an automobile industry culture which some of them where desperately lacking.

Currently, in addition to AutoEuropa, another five facilities assemble passenger, light commercial vehicles and trucks with a total production volume of approximately 271 000 vehicles in 1997 of which 25 000 corresponded to the Renault plant. Table 6 presents the evolution of the overall vehicle assembly. As we can see, from 1987 to 1997, the number of vehicles produced increased by a factor of 2.2. Nevertheless, during 1999, the Ford Lusitana plant, where the Transit model was being produced, ceased activity. The Ford facilities have since then been acquired by Opel.

Table 6 - Vehicle Assembly in Portugal

	Light Passenger	Light Commercial	Heavy Commercial	Total
1987	70830	28294	4269	123897
1988	71088	32738	4637	136524
1989	73178	35952	4353	146087
1990	60221	47881	2966	137687
1991	71973	44585	2940	141377
1992	96179	38719	3576	163226
1993	60075	39008	1984	122207
1994	37754	73029	1437	125209
1995	73185	73940	1688	158895
1996	152646	71782	1952	233132
1997	186010	82755	3791	271737

Source: AIMA (1987 – 1996); AFIA (1997)

Table 7 - Vehicle Assembly per Line (1997)

OEM	Plant Location	Passenger	Light Commercial	Heavy Commercial	Total
AutoEuropa	Setúbal	131.400	-	-	131.400
Opel Portugal	Azambuja	7.569	56.195	114	63.878
Citroën Lusitana	Mangualde	28.725	-	-	28.725
SODIA (ex-Renault)	Setúbal	18.316	6.699	-	25.015
Ford Lusitana	Azambuja	-	9.909	-	9.090
Mitsubishi Trucks	Tramagal	-	4.115	3.150	7.265
Salvador Caetano	Oporto	-	5.837	527	6.364

Source: AFIA

As such, only five plants are presently producing vehicles, and simultaneously two plants with a total yearly productive capacity of approximately 90 000 vehicles are awaiting decisions on their future.

2.2.2 Present Situation of the Portuguese Components Industry

Initially strongly coupled to the national downstream value chain, the components industry has gradually been gaining ground in other markets and its dependency on the Portuguese assembly lines is diminishing. As was previously mentioned, this situation has partially been induced by the public policies outlined for this industry that have aimed at boosting its capacity and importance at a national and international level.

According to the configuration suggested by the International Motor Vehicle Programme (IMVP), cited by Veloso *et al.* (2000), most Portuguese companies are subassembly manufacturers, that is process specialist with additional capabilities such as machining and assembly that are responsible for the design and testing of the component(s), but not the design of the entire subassembly or other components. As a consequence of this reality, a significant part of local demand, more specifically for integrated components, subassemblies, and systems cannot be filled by national enterprises. Consequently, the assemblers have to resort to foreign suppliers, some of which do not possess production facilities in Portugal. These companies have been responsible for the higher value added components that demand significant capabilities in systems design which are normally lacking in Portuguese enterprises.

As process specialists, the national components companies have developed around a limited number of core competencies, incorporating new technologies so as to maintain or gradually increase the added value of their products. Although this may seem to represent the natural evolution of most companies in this sector of activity, the relative lack of tradition of Portugal as an automotive components producing country, signifies that many of these companies are in an initial stage of this process.

Nevertheless, the concentration on a limited number of technologies has permitted the rapid growth of this industry as can be seen by an analysis of Table 8, where the total turnover of this sector has nearly been multiplied by nine in a period of only 12 years. The volume of exports has grown accordingly, making this industry the second largest exporter. This seems to indicate that the public policies outlined for this sector, namely the 1980 policy that sought to boost exports, have yielded quite positive results.

Table 8 - Portuguese Components Industry Evolution

	Internal Market	External Market	Int/Ext (%)	Turnover
1986	40	45	89	85
1990	66	160	41	226
1994	87	358	24	445
1997	250	460	54	710
1998	271	465	58	736

Source: AFIA. *Values in billions of PTE*

The importance of this sector within the Portuguese economy can further be evaluated by the analysis of the following tables.

Table 9 - Importance of the Automotive Components Industry in the Portuguese Economy

	Value	Contribution to Total
FDI (1996)	PTE 178 158 000 million	18% of Manufact. Industry
GDP (1996)		approx. 7%
Exports (1999)	PTE 460 000 million	11%
Employment – Components (1999)	37000	4% of Manufact. Industry

Source: (Veloso et al., 2000); AFIA

Table 10 - Number of Employees in the Automotive Components Industry

1986	1987	1994	1998	1999
21000	21300	34500	36000	37000

Source: AFIA

On the other hand, the importance in terms of the contribution of the automotive industry towards the Portuguese economy, and the development of industry in general, is widely recognised by the Portuguese Government. The Secretary of State of the Economy, Vítor Santos, recently reaffirmed this recognition when he stated that: "The importance assumed by the automotive industry within the Portuguese Economy is widely known. In fact, not only in what concerns vehicle assembly but also components production, this industry, which is characterised by its transversal nature, has been assuming an ever greater role in the development of Portuguese Industry" (INTELI, 2000).

Assuming and maintaining this role requires being at the forefront of technological development. The existing weaknesses in product development suggest that, for the time being, this industry must continue to serve as an example in terms of manufacturing excellence, hence the focus of this thesis on the components companies' manufacturing capabilities.

In terms of the products manufactured in Portugal by the automotive components industry, there is a certain predominance of (1) engine components, suspension, chassis, (2) interiors and (3) electric equipment. Within these three sectors, the number of national companies is substantially smaller. Namely in what concerns electric and electronic equipment, this sector is dominated by large foreign companies.

Table 11 - Automotive Components Sales by Product Group

Product Groups	1992	1993	1994	1995	1996	1997
Engine Components, Transmissions, Brakes	84	108	117	127	151	168
Body Components, Suspension, Chassis	23	34	37	40	70	77
Interiors	60	80	86	102	168	190
Electrical Components	88	101	110	114	148	175
Tires	23	9	10	19	24	27
Buses, Tilting Wagons, Vehicle Bodies	61	63	68	68	53	57
Other (Moulds, Tools, Steel)	11	15	17	14	15	16
Total	350	410	445	484	629	710

Source: CEIIA. Values in Millions of PTE

The above numbers, which reflect the high growth rate this industry has experienced, have been explained over the years through a set of competitive advantages which are partially shared by the rest of the Portuguese economy. According to Investimento, Comércio e Turismo (ICEP), an official institution dedicated to the promotion of the Portuguese economy throughout the world, some of the main advantages of investing in Portugal are (ICEP, 2001):

• Competitive labour costs: Portugal has some of the lowest hourly industrial labour costs in Europe -- one-third of the EU average;

• Significant spending on training: One of the Portuguese government's incentive programs, PEDIP II, allows investors to receive 100 percent coverage for training costs and up to 50 percent for training materials;

• Hard-working labour: According to a survey published by the Institute of the German Economy in 1996, Portuguese workers were no. 2 in the number of hours worked, averaging 42 hours per week;

• Low language barriers: There are minimal language barriers between foreign managers and the local work force. Most Portuguese are multilingual, commonly speaking English and French in addition to their native Portuguese. Every Portuguese student is required to study two foreign languages. Portugal spends 5.5 percent of GDP on education, more than France, Spain, Germany, and the United Kingdom;

• Low unionisation: Strikes in the private sector are rare. In 1996, Portugal was one of the European countries that experienced the fewest number of working days lost due to strikes.

Since past public policy relating to this sector of activity has been widely based on these assumptions, Chapter 4 will analyse, through the use of case studies, if in fact these correspond to the reality in which the companies operate.

2.2.3 Relevance of Stamping in the Pool of Technologies used by the Portuguese Automotive Components Industry

Stamping is the core technology of a significant number of Portuguese automotive components companies. In fact, and as can be seen in Table 12, 23 of a total of 166 companies, manufacture stamped products.

Table 12 - Components Companies by Sub-sector

Sub-sectors	Nº of Companies
Stamped Components	23
Electrical and Electronic Components	19
Seats	17
Interior and Exterior Components	16
Plastic Components	13
Rubber Components and Tires	12
Wire Harnesses	11
Steel and Iron Foundry	11
Moulds and Other Tools	9
Paint	6
Springs	5
Light Alloys	4
Batteries	3
Reinforced Plastics and Composites	3
Other	14
Total	166

Source: AFIA

Simultaneously, some of the technologies which commonly exist within the stamping companies, namely assembly through fastening and welding, and painting, are horizontal to the sector as they are present in a significant number of companies that manufacture other types of products.

Moreover, the great majority of stamping companies are nationally owned, a situation that contrasts with the reality of companies in other sub-sectors. Sub-sectors such as the wire harnesses industry are strongly dominated by multinationals whose decision and engineering centres are situated outside Portugal. Consequently, any work undertaken in such companies would clearly have a smaller impact on this industry at a national level.

3 RESEARCH QUESTION AND METHODOLOGY

3.1 RESEARCH QUESTION

In markets that are not protected by barriers to international trade, products cannot be made available as exports at prices lower than the prices prevailing in the exporting country. On the other hand, the absence of protection of domestic markets ensures that prices prevailing in that market reflect the actual cost of production. Under these conditions, the prolonged presence of a company in that specific market can only be based on a competitive advantage. Such an advantage can result from favourable conditions found in the firm's environment (e.g. cheaper prices of resources used to produce goods) or/and in the efficiency of its past use of resources. These resources may correspond to investments made in the past in, for example, R&D and advertising. They do not only encompass investments made in the processes that produce the company's goods or services but equally investments made in leveraging the attractiveness of the firm's products.

Considering the various possible sources of firm level competitiveness in competitive markets open to free trade, the main research question addressed by this dissertation is:

What are the main competitive advantages of the Portuguese automotive components stamping companies? Are these competitive advantages a result of an efficient use of resources or favourable conditions found in the firms' environment?

To answer this question, a competitiveness model will be developed and applied to three Portuguese automotive components stamping companies in order to assess their advantages in relation to international competition. The competitiveness model and the overall methodology used to answer the research question are described in points 3.2 to 3.5 of this chapter.

3.2 COMPETITIVENESS MODEL

As previously mentioned, the main objective of this thesis is to identify the main competitiveness factors of the Portuguese automotive stamping companies. The definition of competitiveness at the firm level which shall be used in the case study analysis is in accordance to the concepts and measures of competitiveness considered by McFetridge (1995).

In general terms, a firm's competitiveness depends on its profitability, or in other words, on its average cost and the market value of its products. Profitability is a sufficient indicator of current competitiveness, although profitability is best measured over an extended period. On the other hand, the factors that influence profitability vary between homogeneous-product and differentiated-products industries.

In a **homogeneous-product industry** a company may be unprofitable because its average cost is higher than that of its competitors. This can happen due to a number of reasons, including lower productivity levels, higher cost of inputs, or both. Management efficiency and scale efficiency, in turn, contribute towards defining productivity levels.

As such, average cost (relative to its competitors) can be interpreted as a reasonable indicator of competitiveness unless current low costs are achieved at the expense of future profitability.

In profit-maximising equilibrium, the lower a firm's marginal or incremental cost is relative to its competitors, the larger is its market share and, other things being equal, the more profitable it is. Thus, market share reflects input cost and/or productivity advantages.

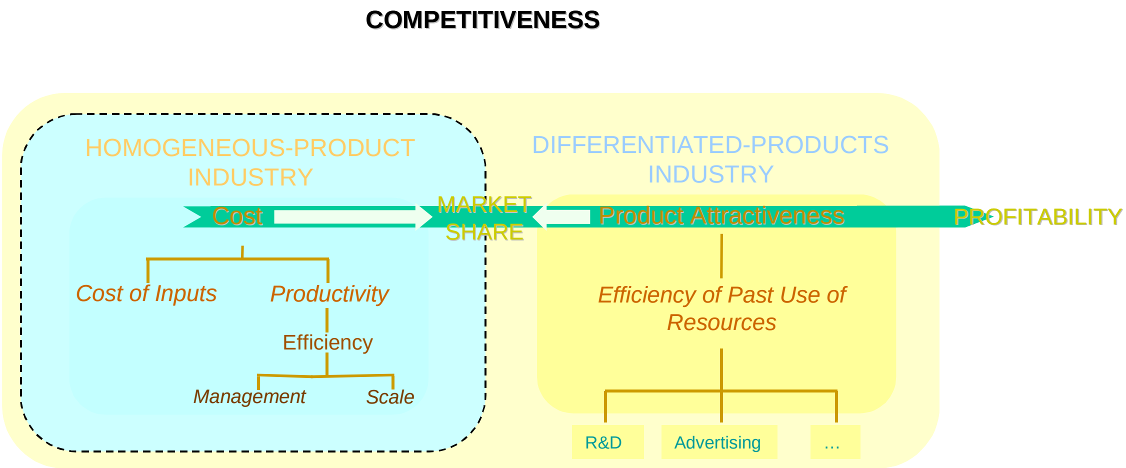
In a **differentiated-products industry** a firm may be profitable for reasons similar to those presented for a homogeneous-product industry as well as due to the attractiveness of the products offered. Other things being equal, the less attractive a firm's product offering, the lower its market share. The attractiveness of a firm's products may reflect the efficiency of its past use of resources. Advertising and R&D investments are some examples of resources which, when made in a specific period of time, help define the future attractiveness of a company's products.

For both homogeneous-product and differentiated-products industries, market share is a good indicator of competitiveness if the firm is maximising profits, and not sacrificing profits in the pursuit of greater market shares. As noted above, these concepts of firm level competitiveness can only be applied to companies operating in markets that are not protected by barriers to international trade, since a firm in a protected market may be profitable, have a large domestic market share and still be internationally uncompetitive.

In a homogeneous-product industry, cost is the key product attribute valued by clients. Therefore, the efficiency of the past use of resources and its contribution towards future product attractiveness is not considered.

A schematic representation of the concepts used in this thesis for analysing a firm's level of competitiveness is presented in Figure 7.

Figure 7 - Schematic Representation of the Analysis Methodology



The complexity associated to defining competitiveness requires that an analysis be made at different levels:

First Level - Profitability

Second Level - Market share

Third Level - Product attributes valued by clients (including cost) which help define market share

Fourth Level - Factors defining product attributes (cost of inputs, productivity and efficiency of past use of resources)

Fifth Level - Management and Scale efficiencies

Because core competencies and capabilities existing within the Portuguese components industry are in manufacturing, the analysis in Chapter 4 will primarily focus on manufacturing performance and operations strategies as the main factors which contribute towards productivity. The analysis of the remaining reality will thus stem from the characterisation and evaluation undertaken at the manufacturing level.

Nevertheless, analysing production strategies and manufacturing performance requires an understanding of the overall business strategy of the company and its competitive positioning in the market, hereby identifying what differentiates the enterprise from its competitors.

The general characterisation of the automotive industry presented before will provides the context for the challenges and opportunities the companies face as well as for the business and operational decisions made in the past, which collectively may have given rise to the differentiating factors we are seeking to identify and better understand.

In addition, the continuous and significant changes this sector has experienced in the past will most likely continue in future limits the value of an analysis solely based on a static view of the market. Therefore, identifying possible development scenarios for this industry, based upon the knowledge of its past and present, is essential to capture the sustainability of the competitive advantages of the firms.

The empirical part of the work is based on case studies of companies whose core competencies are in stamping. Whenever possible, a comparative analysis will be established between the Portuguese results and those of companies in different countries. This analysis will seek to identify and understand the main differences between national and foreign companies in the areas that directly impact their competitiveness.

The analysis of the production process will be based on the use of Technical Cost Modeling (TCM), a tool that allows a structured approach and therefore enables a comparison between companies. A more detailed description of the use of this tool will be made later in this chapter.

The relevance of this study is partially dependent on the extent to which the results obtained through the case studies discussed in this thesis can be extrapolated to the remainder of the Portuguese stamping companies.

Assuming the conclusions reached with these case studies are in fact relevant to the remaining Portuguese automotive stamping supplier industry, we expect to contribute to a better understanding of the stamping companies operating in the components industry and their competitive advantages.

3.3 MANUFACTURING PERFORMANCE MEASURES

Anupindi *et al.* (1998) analyses the performance of a process through the assessment of its ability to provide the desired product attributes from a set of given inputs. These authors aggregate product attributes into four key characteristics, namely **cost, quality, product delivery response** and **product variety**. The fourth, relating to product variety, is less important in an industry strongly oriented towards the manufacture and supply of commodity products (Anupindi *et al.*, 1998), which is the case of the Portuguese components industry.

By establishing a parallel between product and process attributes Anupindi considers the following process attributes: **process cost**, **quality, flow time**, and **flexibility**.

The following parallel between product and process attributes can thus be inferred.

Table 13 - Correspondence Between Product and Process Attributes

		Product Attributes			
		Cost	Delivery	Variety	Quality
Process Attributes	Cost	X			
	Flow Time		X		
	Flexibility			X	
	Quality				X

While product variety *per se* may assume little importance for a specific client in a commodities market, for a process-oriented firm, it represents a possible solution to maximising capacity utilisation. By supplying a wide variety of products or services that resort to common resources existing within the firm and by assuring efficient process changeovers between different products, a reasonably wide product portfolio can be maintained and capacity utilisation maximised. As such, the evaluation of manufacturing process performance and general operations strategies will be made in accordance to the following four dimensions of process attributes considered by Anupindi *et al*. (1998).

Cost

Assesses the company's process efficiency by accounting for all costs associated to the various process inputs essential to a specific output. When evaluating costs it is important to distinguish between those that are essentially the result of actions on the part the enterprise (e.g. labour hours) from those that, although the organisation has a capability of influencing, are essentially determined by its environment (e.g. labour or raw material costs).

Flow Time

Is the time taken to transform a flow unit from an input into an output. Moreover, since adequate process control can be translated into an increase in output per time unit, it can equally be seen as a measure of the extent to which the company masters the various technologies that support or constitute the production process. A combined analysis of process flow time and flexibility is equally important as these two process attributes are normally negatively correlated (higher levels of automation, on the one hand, reduce flow time but, on the other, may reduce flexibility)

Flexibility

Flexibility is generally regarded as the ability to respond to or conform to new situations and is usually classified as process, product, or infrastructure-related (Gerwin, 1993). From the point of view of assessing manufacturing performance special focus will be given to two indicators: set-up time and lot sizes.

Quality

The quality of a product, service or process can be defined as the characteristics that bear on its ability to satisfy stated or implied needs. From a manufacturing process point of view, quality can be seen as the ability to deliver products that are in accordance to the strategic and operational objectives of the company and adequately respond to internal and external requirements. At this level, the analysis shall be centred on the internal operational objectives which will later be correlated with the external and strategic objectives. Since most internal requirements can be expressed either in terms of cost, response time or flexibility, this analysis will focus on measuring quality by using two quantifiable indicators – breakdown and deject rates.

A company's manufacturing process efficiency can be assessed by directly comparing process attributes to industry benchmarks. While this can give us an idea of a company's performance in relation to that specific process attribute, the implications of introducing changes to the manufacturing process, in order to reduce the gap to the benchmark, can best be measured by analysing changes in cost. Since changes in a specific process attribute normally have implications on the remaining, directly comparing process attributes to industry benchmarks can be misleading if the relation between attributes is not accounted for.

This dissertation will utilise these two approaches, that is, (i) identify relevant manufacturing benchmarks, assess the factors that contribute towards possible differences in performance and define strategies for reducing possible performance gaps, and (ii) identify relevant manufacturing benchmarks and assess the impact on the process of changing the process attributes in accordance with the benchmarks.

This second approached requires the development and application of cost models that relate changes in process inputs to changes in cost. The following section will describe three different cost modeling techniques and explain the reasons underlying the choice to use Technical Cost Modeling.

3.4 COST MODELING

Over the years, cost estimation techniques have evolved from simple rules of thumb to relatively complex models. This evolution has been primarily motivated by the growing complexity of products and processes, and the ever-increasing pressure on performance improvement motivated by tighter competition. Notwithstanding the fact that in more developed societies and in the case of some products, price is no longer the main factor determining the customer’s choice, price (cost) remains an important factor in the sense that it determines whether a specific product is profitable or not. Cost models continue to be important instruments in establishing the price at which products and services are commercialised and in the optimisation of processes and activities, although they have to be increasingly complemented with other instruments that assess such factors as quality of service, customer retention and satisfaction, and employee loyalty. A quick overview of the most frequently used cost modeling techniques and their strong and weak points will now be made.

Rules of Thumb

Rules of thumb are widely used in the estimation of costs. According to a rough and ready rule, normally based on previous experience and on the use of a reduced number of inputs, a cost estimate is produced. They are often based on two of the core cost drivers of any manufacturing activity: material cost and cycle time (Busch and Field III, 1988). The same author identifies three major problems in the use of rule of thumb techniques, namely, these rules rely heavily on historical data and are therefore limited when applied to rapidly changing environments. They assume linear relationships between factors driving cost in situations in which relations may not be linear. Finally, they do not contribute in a significant manner to understanding the interplay between the several factors that drive cost. According to German (1998), these approaches lack the key ingredient necessary for analysing changes on the manufacturing process, the ability to understand the dependence of the output (cost) on the changes in the input parameters, such as production volume, lot sizes, etc.

In relatively stable environments and in the case of the dominance of direct costs over overhead costs, this technique has the advantage of being simple in its construction and utilisation.

Traditional Cost Accounting Techniques

Traditional cost accounting allocates costs according to three basic categories; direct labour, raw materials and overhead costs. Maintenance, utilities, equipment, and building costs are usually considered overheads. While in the case of the two first categories, costs are traced to the products with relative ease, overhead costs are increasingly difficult to estimate using traditional accounting techniques. In fact, these methods of allocation, based on the measurement of a reduced number of direct costs and the estimation of the remainder of the costs and their allocation as overheads, were effective until the first half of the 20^{th} century, when direct costs were a significant metric of cost consumption. But this solution is no longer adequate in a context in which overhead costs are frequently substantially higher than the direct costs.

The realisation that cost estimates obtained using these techniques frequently differed in relation to "real" costs in an order of magnitude led to the need to develop new cost modeling techniques based on lower level information, pertaining to processes and activities. Advances in the field of management accounting led to the development of Activity-Based Costing (ABC) that, by choosing smaller cost pools that seek to capture all process or activity inputs, estimates the cost per unit of output of the process or activity. Activity-based costing differs from traditional cost accounting in the selection of a larger number of more appropriate bases for allocation. Miller (1996) defines activity-based costing as a methodology that measures the cost and performance of activities, resources, and cost objects, in which, resources are assigned to activities, and activities are assigned to cost objects based on their use.

The criticism of the ability of ABC to contribute towards management decisions has lead to the emergence of relatively recent disciplines such as Activity-Based Management (ABM), which draws on information produced by applying ABC methodologies, but focuses on the management of activities as the route to improving the value received by the customer and the profit achieved by providing this value (Miller, 1996). Oliver (2000) defines ABM as a discipline that focuses on the management of activities to continuously improve the value that the customers receive.

Technical Cost Modeling

These cost estimation techniques are relatively limited when it comes to undertaking an in-depth analysis or investigating the effects of changes in input variables on manufacturing cost because most do not relate final cost to process parameters, but instead estimate the cost based on a limited number of inputs such as material, equipment and labour costs. Technical Cost Modeling (TCM), initially developed by the Massachusetts Institute of Technology in the Materials Systems Laboratory (German, 1998; Veloso, 2001), seeks to overcome some of these limitations.

TCM is specifically designed to investigate the interactions between process variables and cost. TCM breaks down the different cost elements and estimates each one separately. This is done from basic engineering and physical principles of each of the manufacturing processes involved in the overall operation. Clearly defined economic and accounting principles are then applied to these cost elements (German, 1998).

TCM focuses mainly on manufacturing costs and is less adequate for estimating total cost (i.e. including overhead, etc) of a product. Therefore, it is more suited to situations where the exact total costs is not essential. This occurs when we are essentially interested in a comparative analysis between competing technologies within a company, or when we are benchmarking companies with similar structures where the remaining costs are assumed to be approximately identical.

Just as any other model, the value of TCM is strongly dependent on the quality of the inputs and the process competencies of the user. Cumulative knowledge assumes a very important role when TCM is used as a benchmarking tool since comparisons can then be made with a virtual enterprise.

3.5 DETAILED DESCRIPTION OF THE STEEL STAMPING TECHNICAL COST MODEL

Introduction

Before proceeding with the description of the models used in the case studies, an overview of the manufacturing processes used by the companies will be made. A general understanding of these processes is essential because the structure and the functioning of the models are largely determined by the processes themselves and by the characteristics of a typical stamping company. Albeit limited, this knowledge will equally give us a more critical perspective of the various outputs of the models.

The model used in the analysis incorporates the core technological competencies of stamping companies, which are the blanking and stamping technologies, as well as a number of other technologies which are commonly used by the Portuguese stamped automotive components enterprises. These technologies have been gaining ground in terms of value added in relation to the stamping technology and have simultaneously been essential to most national companies in their efforts to maintain a first tier position.

The final characteristics of a product are the result of the nature of the raw materials used in its production and of the successive application of transformation and assembly processes. When developing a model aimed at simulating production processes, the main aspects under analysis are the nature of the technologies that together constitute the manufacturing process as well as the type of interaction existing between them. These aspects pertain to the more “harder” factors involved in the manufacture of a product. The choice to resort to mathematical models which are based on engineering and physical principles of the technologies and materials processed does not permit us to directly incorporate the “softer” factors which result from the application of individual or collective knowledge to the process. These factors must therefore be seen as intangible inputs that act upon the process resources and inputs, and which partially determine the company's manufacturing performance. As such, they are an essential part of the explanation of the results obtained with the simulations, notwithstanding the fact that no direct relation can be established between their nature and the models' outputs.

General Description of Manufacturing Process

The growing importance of metals other than steel in the production of vehicles and their components has not yet displaced steel as the main raw material. This fundamental input is delivered to the stamping companies either in the form of blanks or metal sheets. A blank is a pre-cut metal shape ready for a subsequent press operation, which has been produced by cutting dies.

Since some companies outsource the production of blanks, for these companies the first technology to be applied to the raw material is stamping. This is one of the many processes available for working metal to a desired shape. Stamping is the general term used to denote all sheet metal pressworking. Depending on the form of the raw material (blank or sheet) and the presses available in the company, three main stamping processes can be used, namely, tandem press lines, progressive die stamping or transfer presses. Since most components are constituted by more than a single stamped part, different processes may be applied to different parts.

The next process is normally an assembly operation in which the various parts of the components are fixed together by mechanical means. While some of the fixing elements are bought from suppliers, the various stamped parts are normally produced by the company itself.

Besides fastening, welding is equally used as an assembly method. Many metal welding processes have been developed and perfected, and are currently available (laser, arc, brazing, gas, resistance etc.). Due to the large diversity of metallic raw materials and the distinct characteristics of the components being produced, the automotive industry applies many of these welding techniques in the manufacture of its products. This technology is very similar to fastening in terms of set-ups and production lead-times as well as in the type of interaction with upstream and downstream processes.

After all the metallic parts are assembled, the assembly receives a paint coating which increases the resistance of the part to chemical and physical agents. Given the type of parts to be painted and the required surface characteristics, electrophoresis is widely used by stamping companies. This process consists in the migration of charged paint particles, through a solution under the influence of an applied electric field, which are finally deposited on the surface of the component. Electrophoresis equipments are normally quite large due to the succession of different treatments the components undergo (washer, dip tank, spray booth and dryer) and conveyor systems with hangers are used to transport the components along the line. At the end of the line the components are ready to be shipped to the client.

Due to the fact that manufacturing layouts in stamping companies are normally process oriented, intermediate parts have to be transported to the next process in the containers in which they were manually or automatically placed. The limited exchange of information between sequential processes is circumvented through the use of buffers that guarantee that the day's production schedule is reasonably adhered to. At the end of the day, information on the progress of the different processes is collected, analysed and used to fine-tune a previously defined production schedule for the next day.

Model Inputs

The initial step in a TCM analysis is to identify the various manufacturing processes that are used in the production of a specific product. Algorithms describing the various phenomena associated with a process are then constructed and used to predict process characteristics such as the consumption of raw materials and cycle time which are then directly related to cost factors such as the cost of raw materials and labour used in the manufacturing process. In these conditions, model inputs could include such factors as raw material characteristics and the price of labour.

Within the set of inputs we can distinguish between exogenous, plant, part, and process specific variables. The exogenous variables basically characterise the enterprise's interaction with its environment in a quantitative manner. Plant data relates to information that is not specific to any part or process but to the organisation as a whole. Working hours, downtimes and workers per category are some examples of plant wide data. These two groups of variables are thus plant and part generic, that is, are independent of the product and process under analysis. The product variables define the characteristics of the part, namely, its geometry, weight, the raw materials and their cost, and production volume, among others. The remaining inputs, that is the process inputs, require a great understanding of the engineering and physical principles underlying the technologies, which when coupled to expertise in process implementation, will permit an estimation of the number of workers, times, equipment characteristics and costs, lot sizes, space occupied, etc. As previously mentioned, any model estimations are overridden when real company data is available.

Model Outputs

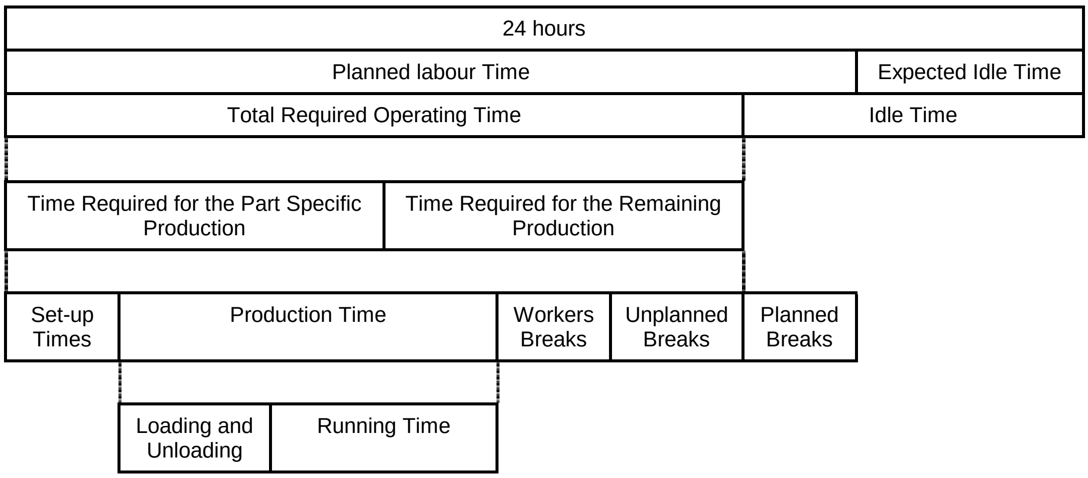
The outputs we are seeking are total cost and its division into relevant cost elements. In relation to the cost elements, a division between fixed and variable costs is made. The first can then be subdivided into equipment, tooling, maintenance, overhead, and building costs. Cost of capital is considered in all investments, namely, in equipment, tooling, and building. In what concerns variable costs, a division is made according to three categories, namely, labour, energy, and raw material costs.

Model Assumptions

Since it is not possible to make a detailed description of all model assumptions, special attention will be given to those which effectively constitute the model's foundations. Among these, time is probably the factor that assumes greatest importance as its precise measure and correct allocation to a specific task can sometimes be far from straightforward.

- Unless otherwise stated, manufacturing processes are assumed to be fully occupied throughout the year. This means that fixed costs with equipment, buildings etc. are assigned to a component in accordance to the portion of time spent on the resource. This does not necessarily mean that the resources are used to their full capacity throughout the day, as many non-productive time periods can occur. Understanding and characterising these different times is essential if the running time (time during which parts are effectively being produced) is to be known. By knowing the daily running time, number of working days per year, and the cycle time of a specific process it is possible to estimate the total annual output of that same process. As previously mentioned, this information will then be used to allocate fixed costs to the different components which are annually produced using that process. German (1998) subdivides the 24-hour period in the following manner.

Figure 8 - Division of the 24 hour Period



- A 10-year equipment life is considered and equipment costs are calculated in the form of loans with constant payments and constant interest rates.
- In relation to tooling investments, costs are distributed among the overall production volume for the specific component during the product's life. Tooling costs are equally calculated as loans in which constant payments are made at constant interest rates.
- Defect rates associated to the different processes consider the added value of the intermediate products manufactured. Thus, when a specific part is scraped, all costs, which until that stage have been incurred, are accounted for. On the other hand, all rejected parts are considered waste and, as such, are not reworked. Since, the case studies analyse real manufacturing processes and components, data pertaining to raw material requirements and waste, correspond to real production data and not estimates.
- Energy consumption is based on the physical principals of the materials being processed and on the technical characteristics of the production equipment.
- Building costs are calculated as a portion of the overall building costs based on the area occupied by the different processes and on current prices per square meter of space and construction. The building life considered is 30 years and costs are uniformly distributed over this time. Building

costs are equally calculated as loans in which constant payments are made at constant interest rates.

Cost Breakdown

Fixed Costs

Equipment Costs

Equipment costs refer to all investments made in the acquisition of the main manufacturing equipment, auxiliary equipment, and installation costs. Various factors influence this cost, namely, part geometry and raw material, desired machine output, and the level of automation.

Tooling Costs

For the processes under analysis, tools are normally specific to a given part and their cost can only be distributed among the total amount of parts that will be produced during the tool's lifetime (or that of the product). This situation contrasts with that of the investments in equipment which are normally not part specific. In the case of small production volume components, tooling costs can assume some relevance.

Building Costs

Are the costs associated to value of the land and construction cost equivalent to the space occupied by the manufacturing and auxiliary equipment.

Maintenance Costs

Measures the cost of maintaining the manufacturing and auxiliary equipment operational. The value attributed to each process depends on the maintenance cost of the equipment used in the production of the specific part weighted by the total production volume on that same equipment. When no data is available, this cost is assumed to be a percentage of the investment in equipment.

Overhead Costs

Relate to indirect costs, that is, the costs that can not be directly allocated to the processes under analysis. These account for general organisational costs such as clerical and management salaries, etc.

Variable Costs

Raw Materials

Account for all the raw materials used in the production of a given part. The final value considers the cost of primary and secondary materials and subtracts the value received for recycling the scrap produced. For the companies under analysis, the primary raw material is either coil steel or steel blanks and the secondary materials range from paint to screws and bolts for fastening. The model only considers the recycling of the primary materials, that is, the intermediate and final steel waste and defective parts produced.

Labour Costs

Measures the costs associated to the workers directly related to the different manufacturing processes. These do not account for any workers besides the ones associated to the various equipments used in the production of the component under analysis. Consequently, costs relating to shop floor logistics workers are considered as an overhead cost.

Energy

Assesses the energy consumed by the equipment directly associated to the manufacturing process. This value is either based on information relative to energy consumption or on the analysis of the physical principles of the process.

Process Cost Division

Simultaneously, a second cost division is made according to the different technologies that together make up the manufacturing process. This permits an understanding of the product's cost structure according to the technologies which are responsible for the costs incurred. These two divisions permit a basic understanding of the product's cost structure, which constitutes the first step in the identification of the origin of a specific cost and in the minimisation of overall cost.

4. CASE STUDIES

The data used in our analysis corresponds to information from three Portuguese stamping companies. A number of distinct data collection procedures were used, namely, interviews with the General Managers and CEOs, a tour of the overall facilities which was normally accompanied by the different heads of the department, and the use of questionnaires. The questionnaire used for characterising the manufacturing processes associated to the production of the components under analysis is presented in the Appendix.

In two of these companies it was possible to collect data relative to two parts and, as such, data from five components was available for analysis.

Due to reasons of confidentiality, information that could lead to the identification of the companies or the components analysed will not be presented. Simultaneously, non-aggregated analyses will prevail, since we consider this to be the best-suited methodology for attaining the desired results.

4.1 GENERAL COMPANY AND COMPONENT CHARACTERISATION

4.1.1 Company Characterisation

Since a more in-depth analysis of the manufacturing process will be made later on in this chapter, the information that follows pertains to generic company data that is essential to the characterisation of the companies studied.

Table 14 - Generic Company Data pertaining to the Case Studies

	1998	Evolution (1994 – 1998)
Average n. of Years of Activity	36	
Nationally Owned	100%	Unchanged
Percentage of Business in Auto.	92%	3% Increase
Exports	52%	
Exports E.U.	37%	
Average n. of Employees	261	35% Increase
Average Turnover	$ 12 911 368	100% Increase
Average Investment	$ 2 369 357	52% Increase

As can be seen in Table 14, these companies have experienced quite substantial growth during the 1994-1998 period. This growth is apparent both in terms of the number of employees and turnover, and in the level of investment.

Similar growth has characterised these companies' 36-year average history, since all three enterprises evolved from small family-owned and managed businesses.

As will be readdressed later on in this chapter, the percentage of overall business pertaining to the automotive industry has evolved positively, reaching figures close to 100% in 1998.

In relation to quality certifications, two companies are ISO 9002 certified and one is ISO 9001. These companies are presently seeking to evolve to ISO TS 16949 (specific to the automotive industry) and ISO 140000 (environmental) certifications. At the time this data was collected in 1999, companies had been certified according to the ISO 9000, QS 9000, or Ford Q1 Standards, on average, for six years, or in other words, since 1993.

4.1.2 Strategies

In order to place into context some of the present and past choices made at the firms' manufacturing level it is important to understand how the environment in which the companies operate has moulded these options. The aim of this section of the work is thus to characterise the past, current and future strategies of these companies and not to evaluate their appropriateness in view of the specific and general environment conditions.

This evaluation will only be undertaken after the production and operational strategies have been analysed. As previously stated, the focus on manufacturing, which characterises the empirical part of this thesis, derives from this being the main area of competency in nationally owned automotive components companies. Indeed, Veloso *et al.* (2000), in a comparison between product development and manufacturing performance of the Portuguese automotive components companies stated that "While there are many Portuguese companies which still lag behind their European counterparts, increasing numbers of companies, both national and foreign owned, are able to achieve world class practices in the areas of quality, productivity, cost, and responsiveness. (…) Unfortunately in the area of product and process development, the Portuguese firms often lack important capabilities".

Market and Product Strategies

The three components companies can be characterised as generically process specialists, that is, companies that with time have accumulated know-how on a limited number of manufacturing processes. This situation clearly contrast with that of the foreign firms operating in Portugal which are normally product specialists and first tier systems and modules suppliers. As process specialists, these companies have successfully integrated a growing number of technologies into their operations in order to capture additional value. This has led to some product diversification, albeit limited to products that utilise similar manufacturing technologies.

Simultaneously, a growing demand for tools and some deficiencies in terms of on-time delivery performance of the tool suppliers, have led to two of these firms, with a core business in stamping, to enter this area of activity. This situation contrasts with what happened in the past where many tool manufacturers entered the stamping business to optimise the use of the presses acquired for testing the tools.

Understanding that tools could be developed and produced according to the tight schedules imposed by OEMs and with added benefits in terms of cost and prestige (OEMs are increasingly looking for one-stop solutions were suppliers are responsible for overall tooling, product development and production), has led two of the three stamping companies to invest in development and production means to fulfil their tooling needs. For these companies, this activity is turning into an integral part of their business. This means, not only supplying their internal "customers" and traditional clients – the OEMs - with tools, but equally other stamping companies which do not have sufficient tooling capacity and the ability to deal with uncertainties in delivery schedules.

Overall, the evolution that has occurred in the automotive stamping industry has essentially been based on the accumulation of manufacturing competencies, with little concern for product development capabilities. These companies have looked at the market as a place where they could sell their manufacturing competencies and not as a group of customers with needs that have to be understood and met.

The advent of closer relationships between suppliers and OEMs, where suppliers are increasingly looked upon as partners, has attenuated this separation and has effectively forced some suppliers to opt for supplying the automotive industry on an almost exclusive basis. The Economist Intelligence Unit sees this new form of interaction in the following manner "Despite the price squeezes, relationships between components suppliers and vehicle manufacturers are no longer adversarial. The vehicle manufacturers are keen to acknowledge their most successful suppliers, as the number of supplier awards now indicates." (EIU, 1997). Once ordered to make parts "to print" for commodity prices, suppliers are now seen as partners in planning, engineering, costing and development (Ernst & Young LLP, 1998). Closer relations between OEMs and suppliers resulted in the former gaining access to previously undisclosed information and consequently being able to detect the significant operational inefficiencies resulting from the great variety of markets being supplied. Ultimately, the pressure on suppliers for cost reductions and overall performance improvement was decisive in the move towards greater market specialisation. On average, 92% of these three companies' turnover is in the automotive industry.

From the supplier's point of view, most of the inefficiencies occurring in the automotive product supply chain could easily be passed on to the products pertaining to the remaining, clearly less demanding, markets. While this strategy could work in the case of cost dilution, it could not avoid other issues such as quality or on-time delivery which are highly valued by OEMs and which were suffering from the lack of focus on a sector of activity which has very demanding specific characteristics. From the OEMs' point of view, the lack of specialisation was clearly incompatible with the efforts being made with the suppliers in the continuous improvement of their overall performance and the level of risk they were willing to support. This evolution was, once more, essentially the result of pressure by the OEMs for change and less a carefully planed positive and proactive step taken by these companies in accordance to a defined strategy.

In what concerns investment in new or improved technologies the perspective adopted by the firms is very similar to that just described, that is, the investment timetable is essentially defined by the clients, because wining or losing a bid for the production of a specific product is frequently determinant to the investment decision process. If we extrapolate the use of these criteria, or any other which is highly dependant on isolated moves made by individual external entities, to the remaining decision taking processes existing within the firms, we can understand the difficulties encountered by these companies in defining coherent long-term strategies. Nevertheless, the growth that has characterised these companies has permitted that added importance be given to strategic planning, and to marketing and commercial activities. As such, some of these handicaps are slowly being overcome, although the small size of these companies when compared to their foreign counterparts continues to be looked upon as one of the reasons behind companies not being able to define more proactive and aggressive strategies. Some very interesting success stories of small companies with well-defined aggressive strategies seem to suggest that the importance of factors related to the size of the companies and the industry at a national level is probably overstated.

Once again, this form of decision-making, which at a first glance can be highly restrictive of a company's development, cannot be analysed without understanding the financial and economic reality of these firms. In fact, the relatively fragile economic situation and the dependency on a small number of large clients, limited the nature and timing of the investments made. As these companies grew in size and financial capability these pressures began to be less acute and investments are increasingly made in accordance to the company's overall strategy, that is, in accordance to its own timings and medium and long-term prospects.

Internationalisation

The limited size of the national vehicle assembly market has led most components companies to commercialise a significant part of their products in foreign markets, namely, Germany, France and Spain, countries in which vehicle assembly assumes greater expression. The fact that European countries have highly demanding consumers is unquestionably a positive factor when assessing this industry's competitiveness and that of the case study companies. Approximately 52% of these companies' turnovers correspond to exports and 37% to sales in the E.U. The fact average turnover in the national market is quite high suggest that geographical proximity to clients may have a relevant influence on the companies' competitiveness. Considering that the average part under analysis in the case studies has a value/weight ratio of approximately 1.5$/Kg, according to Veloso *et al.* (2000) this would lead to logistics costs accounting for approximately 10% of the overall value of parts shipped from Lisbon to Stuttgart, Germany[1]. On the other hand, the same study pointed towards distance related geographical factors, namely transport, has accounting for an average of approximately 30% of logistics costs. These two values are indicative of the importance that geographical proximity may have on these companies' competitiveness.

[1] A profit margin of 7% was considered for these products

Moreover, only one of companies has internationalised other activities besides commercialisation. We can thus conclude that companies are physically and commercially confined to the European continent. This reality is in clear contrast with current industry trends characterised by the move by OEMs towards global sourcing. Although some subtle differences may exist in the strategy followed by the various OEMs, namely, whether the global supply of a specific component will be made by a single company or by the global supplier together with a local company, the capability to supply geographically disperse markets is currently seen as essential to maintaining a 1st tier positioning within the supply chain (Veloso *et al.*, 2000). The Economist Intelligence Unit considers that “It is not in the vehicle manufacturers’ interest to develop new suppliers for each market. (…) Vehicle manufacturers expect their suppliers to be effective on both a global and regional basis” (EIU, 1997).

According to Veloso *et al.* (2000), the fact that only the larger national firms have internationalised their activities clearly means that the investments required in doing so are so great that critical size has first to be attained nationally before companies can expand their activities overseas. It is thus essential that companies continue to grow, whether by increasing their capacity through investment (brought on by expanding their client base), by mergers and acquisitions or simply through co-operation with other firms. For the smaller companies, who choose to follow strategies which are not based on creating critical size through any sort of resource pulling, the solution may lie in the supply of niche markets where smaller production volumes will probably reduce the need for global suppliers.

Growth Strategies

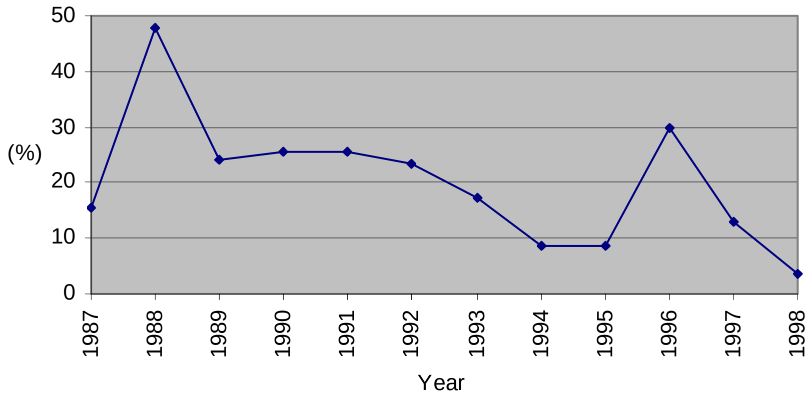
The growth the Portuguese components industry has experienced in the last decades (Figure 9) has largely been based on increasing manufacturing capacity. On the other hand, the wave of mergers and acquisitions that has swept the globe has only partially been felt in Portugal where the use of these types of growth strategies is virtually unheard off. The primary reason behind this situation is related to the prevailing culture in which firms continue to look upon their neighbour as the main source of competition.

In an industry accustomed to extremely high growth rates, companies are now starting to realise some of the negative consequences of growth solely based on increasing production capacity. This has led these companies to pay increased attention to the less tangible side of their activities. Indeed, this unbalanced expansion may be one of the factors behind the deceleration in this industry’s growth rate which can be seen in the following figure (the 1996 growth rate is in part due to this year corresponding to the first year of AutoEuropa production at close to full capacity). Despite any investments that may be made during the following years, the high growth rates that have characterised this industry in the last decades must not be expected to continue unless significant alterations to the existing market conditions take place, namely, the establishment of another large OEM in Portugal. This further emphasises the need for companies to grow in partnership with other companies so as to attain the critical size essential to overcoming many of the size-related obstacles which are now becoming clearer.

The three companies under analysis have equally based their growth strategies on leveraging internal production capabilities. Considering that co-operation between companies could overcome some of the previously mentioned size-related issues while leaving the firms' autonomy virtually untouched, by considering their neighbour as their main source of competition, this strategy has not been pursued.

Albeit through co-operation or individually, companies will tend to grow less in their traditional areas of activity and more in previously unexploited areas, situated upstream and downstream of their present activities. Product design and development and the assembly of more complex products (modules and systems) are two probable areas in which these companies will be seeking to invest in the medium-term. When faced with the substantial investments required and the need to minimise the risk involved in entering these activities, co-operation is finally being looked as a means of developing capabilities in previously unexploited areas of activity.

Figure 9 - Annual Growth Rate of the Portuguese Automotive Components Industry (1987 – 1998)



Source: AFIA

4.1.3 Characterisation of the Production Processes

Although exhibiting some differences in terms of size, structure and product characteristics, the three companies use similar approaches when it comes to manufacturing. The main differences lie in the distinct degrees of automation used in some of the more labour intensive operations such as assembly.

Blanking

As previously stated, steel remains the main raw material used in the production of vehicles and their components, notwithstanding the growing importance of other metals such as aluminium. Steel is delivered to the companies either in the form of blanks or sheets. The shape of the blank is defined according to two main objectives, namely, the elimination of subsequent trimming operations and forming facilitation. The metal sheets are either supplied as flat sheets or in coils. Depending on a number of factors, companies may choose to outsource, produce internally or even opt for a mixed strategy where some blanks are outsourced and other are produced with the companies awn means.

Stamping

Whereas blanking can be seen as a technology which basically prepares the raw material for the subsequent transformation processes, stamping is undoubtedly the most important process, both in terms of its internal importance (measured in terms of the level of investment in presses and labour costs) and in terms of its contribution to the product's characteristics which are valued by the client.

Three main stamping processes are used by the companies, namely, tandem press lines, progressive die stamping and transfer presses. The first is basically constituted by a sequence of presses (normally small in size) on which one (or more) stamping operations are performed on successive presses. When raw materials are fed in the form of sheets, the presses are normally aligned so that the sheet is automatically transferred between the presses, hereby minimizing handling operations and intermediate stocks. If not, the physical distribution of the presses is less restricted, although handling and stock levels can be minimized if adjoining presses are used. In this case, handling operations are required and usually undertaken by workers.

Progressive die stamping is a process in which sheet metal is fed to a press with various stations and the sheet is successively stamped in each station. The distance travelled by the sheet between each press stroke is equal to the distance between stations. In this type of stamping process, the raw material is normally automatically fed from coils, and supervisory and handling operations may be required after the last station.

In what concerns transfer press utilisation, this method consists in the transfer of blanks (which are normally automatically fed to the press) between stations by picking up the blanks from the station where it was stamped and placing it in the next station. Supervisory and handling operations are identical to that of the progressive die. This stamping method is perhaps the most complex of the three due to the precision with which the parts have to be placed on the stations. In addition, this method requires a minimal level of competencies in such areas as electronics and pneumatics, compatible with routine maintenance operations of the transfer system.

The benefits of using progressive die and transfer presses are clearly understood by the companies when applied to the manufacture of the type of products these companies have specialised in, that is, in the production of relatively small parts that require a reasonable number of stamping operations. One can say that the larger stamping companies have all invested in these equipments, assigning them to the higher production volume parts and in some cases these equipments are exclusively assigned to a specific part. As to the advantages, these are normally considered to be in reducing intermediate stock levels and production lead-times as well as reducing non-value adding operations such as transport and handling. On the other hand, the disadvantages are mainly associated to the investment in equipments and to the introduction of automation (in the case of transfer presses) which is an area where internal competencies are generally scarce.

As to die change, available techniques that drastically reduce the amount of time needed to change a die are generically absent, and as such, large die change times are common. As we will see later on, the benefits arising from the use of these techniques in terms of increased production capacity are quite substantial when compared to the investments that are necessary. What is often lacking in the companies is the development and implementation of the correct procedures. This is by no means synonymous to investing in equipment (which often accounts for substantially higher costs), which should only occur when further optimisation of these procedures is no longer possible. Substantial improvements can thus be accomplished with reasonably small investments.

Assembly

The assembly operations are normally welding and/or fastening. In recent years, significant investments have been made in the automation of the welding operations and in some cases even in assembly. The non-automated welding operations are normally characterised by a single worker, who assembles all the components, unless two or more types of welding technologies are required in the assembly of the component. The automated solution usually consists of a welding cell where one or two robots (normally producing the same type of component) are fed by a single worker. This solution has clear benefits in terms of process stability over time, higher production rates, less workers for the same output, but perhaps the most important advantage lies in companies being able to circumvent the lack of highly skilled specialised workers which are fundamental in this technology.

On the other hand, the negative implications of introducing higher levels of automation, in general within the companies and in welding in particular, have to with dealing with a technology in which they have only limited competencies. This limits their capabilities to, on the one hand, exploit the equipments to their full potential and, on the other, resolve the technical difficulties arising from eventual breakdowns. When compared to the investments associated to manual operations, another clear disadvantage lies in the cost incurred in the acquisition of automated displacement and protection devices, and robots etc.

Notwithstanding the variety of welding processes which have been developed over the years, the main factors governing the quality of most of these processes has to do with stability over time, although some of the difficulties encountered in welding and stamping often have their origin in the blanking and stamping operations, especially if the trim stages of these operations are not adequately performed.

Painting

The type of parts to be painted and the surface characteristics which are required make electrophoresis the most widely used painting technology in stamping companies. Since companies, in general, only have one such equipment and this process' production lead-time is large, planning the entire manufacturing process is crucial so that the components are fed to the line in a correct an interrupted sequence in order to utilise all available capacity. Adequately sequencing the introduction of the parts in the line is essential because different components require different line conditions which must be progressively and slowly be changed over time. The rapid modification of these parameters is not possible due to the restrictions imposed by this technology's characteristics, line utilisation, production lead-time and availability of equipments.

But the dominating factor associated to painting is the initial investment which is required to set-up a painting line. As a consequence of this situation only the larger companies possess a paint line. On the other hand, even the larger companies do not have sufficient capacity to fully occupy their own line and are therefore painting parts for external clients.

No significant investments have been made in the last years in this technology and improvements have basically been limited to hanger optimisation.

4.1.4 Component Characterisation

The components under analysis are mainly constituted by steel and pertain to non-visible parts of the automobile. They are essentially non-visible elements that serve as fixtures for other electric, electronic or mechanical components.

The fundamental specifications these components have to conform to are dimensional accuracy and stability over time, and resistance to the application of specific loads. In the case of the components that have mechanical elements attached to them, resistance to loads is of the utmost importance, and consequently, these components are substantially more robust. Moreover, when they are crucial to the vehicle's safety, the components are designed with safety margins that normally lead to even more robust solutions. The emphasis on safety equally leads to less complex components, where factors such as added functionality or weight reduction are comparatively less important. On the other hand, the components that do not have a direct impact on safety are optimised according to a variety of other objectives. This usually leads to more complex solutions.

Being comprised of steel, another important characteristic of these components is their resistance to corrosion. This is achieved by depositing a thin layer of paint on the surface of the component and through the use of raw materials that offer some resistance to mechanical and chemical corrosion agents.

The data pertaining to the individual components under analysis can be seen in Table 15.

Table 15 - Component Data

		COMPANY A						COMPANY B				COMPANY C		
		COMP. 1				COMP. 2		COMP. 3		COMP. 4		COMP. 5		
		Part 1	Part 2	Part 3	Part 4	Part 1	Part 2	Part 1	Part 2	Part 1	Part 2	Part 1	Part 2	Part 3
Annual Production Volume		1712534	1712534	1712534	1712534	44292	44292	300000	300000	140000	140000	340000	340000	340000
Part Weight (kg)		2.079	0.448	0.062	0.037	5.13	4.237	0.58	0.17	0.84	0.017	1.50	0.3	0.15
Raw Material		Steel	Steel	Steel	Steel	Steel	Steel	Steel	Steel	Steel	Steel	Steel	Steel	Steel
Maximum Length (mm)		276	236.6	41	52	780	780	379	126	400	160	310	60	160
Maximum Width (mm)		276	236.6	19	45	700	700	162	114	350	15	310	35	139
Thickness (mm)		3	21	5	1.5		830	1	1	2	1	1	2	1
Final Surface Area (sqm)		0.066	0.012	0.002	0.001	0.92	0.92	0.045	0.006	0.032	0.00028	0.065	0.004	0.005
Projected Area (sqm)		0.056	0.006	0.001	0.001	0.45	0.45	0.021	0.003	0.01632	0.00024	0.041	0.002	0.005
Tier		1st tier				1st tier		2nd tier		1st tier		1st tier		
Product Life (years)		5				5		3		3		8		
Manufacturing Processes	Blanking	X	X	X	X			X	X	X	X	X	X	X
	Stamping	X	X	X	X	X	X	X	X	X	X	X	X	X
	Welding	X	X	X	X	X	X	X	X	X	X	X	X	X
	Fastening	X	X	X	X			X	X	X	X	X	X	X
	Painting	A. A.	A. A.	A. A.	A. A.			A. A.	A. A.	A. A.	A. A.	A. A.	A. A.	A. A.

A.A. – After Assembly

4.2 COMPETITIVENESS ANALYSIS

4.2.1 Profitability

The absolute level of profit, on it's own, is an insufficient indicator of company performance. In order to evaluate profitability, profits must be compared and related to other aspects of the business, namely, with the amount of capital invested in the business, and to sales revenue.

Return on Total Assets (ROTA), Return on Capital Employed (ROCE), net profit margin and net asset turnover are financial ratios that take into consideration these two aspects and will be used to evaluate profitability.

ROTA is a measure of profit in relation to the total assets invested in the business. The total assets of the business provide an indication of the size of the company. ROTA measures the ability of general management to utilise the total assets of the business in order to generate profits.

ROCE considers the capital invested in the business, unlike ROTA, which measures profitability in relation to total assets.

Net profit margin measures profit relative to sales revenue. Higher than average net profit margins for the industry may be an indicator or good management.

The **net asset turnover** ratio measures the ability of management to utilise the net assets of the business to generate sales revenue. A well-managed business will minimise machine and equipment idle time. A high ratio may suggest excessive sales revenue in view of the investment level. Too low a ratio may suggest under-trading and the inefficient management of resources.

According to these definitions, the following ratios will be used to assess profitability.

$$\text{ROTA} = \frac{\text{Net Profit before interest and taxes}}{\text{Fixed assets plus current assets}} \text{ X } 100$$

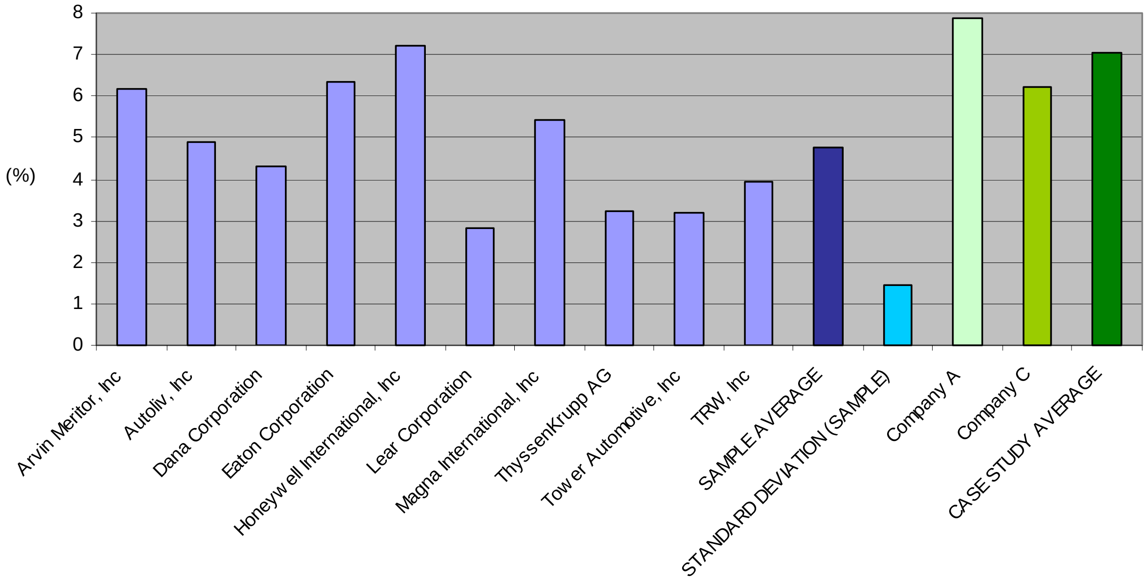
$$\text{ROCE} = \frac{\text{Net Profit before interest and taxes}}{\text{Total Capital Employed}} \text{ X } 100$$

$$\text{Net Profit Margin} = \frac{\text{Net profit before interest and taxes}}{\text{Sales Revenue}} \text{ X } 100$$

$$\text{Net Asset Turnover} = \frac{\text{Sales Revenue}}{\text{Total Capital Employed}}$$

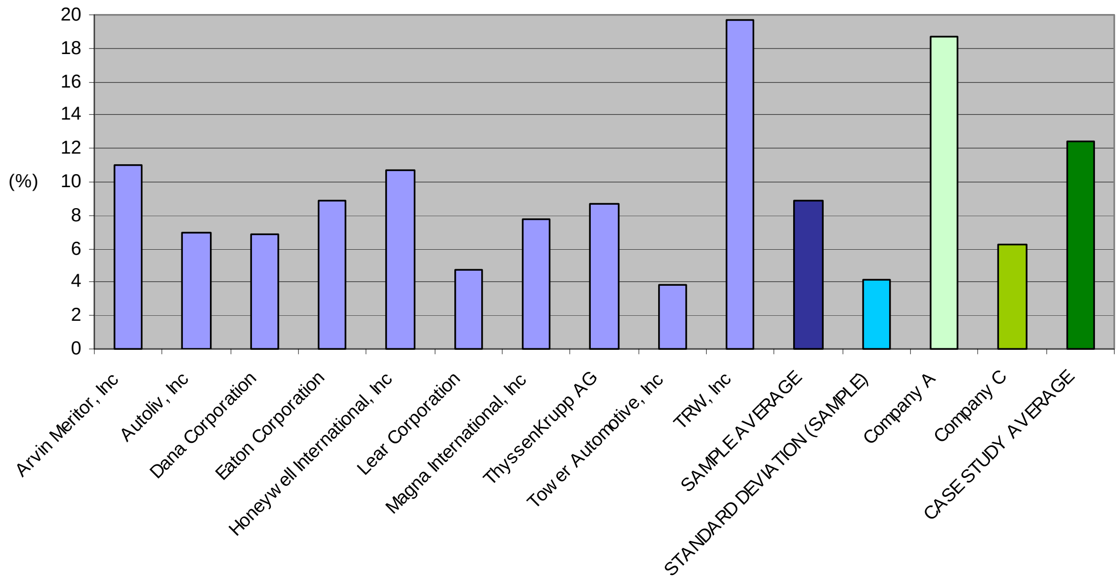
In order to assess the case study companies' profitability, these firms were ranked, according to the above indicators, against a sample of foreign automotive components suppliers. This comparison can be seen in the following figures.

Figure 10 - ROTA of the Case Study Companies and a Sample of Auto Suppliers



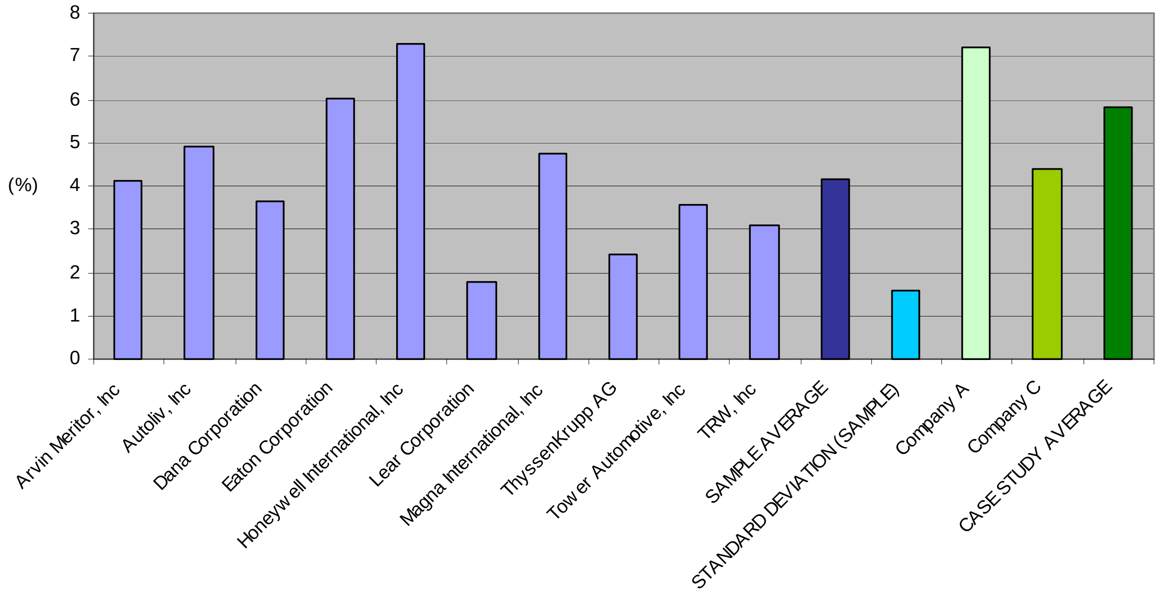
Source: Case Study Data; Hoover's Online (Company Income Statements)

Figure 11 - ROCE of the Case Study Companies and a Sample of Auto Suppliers



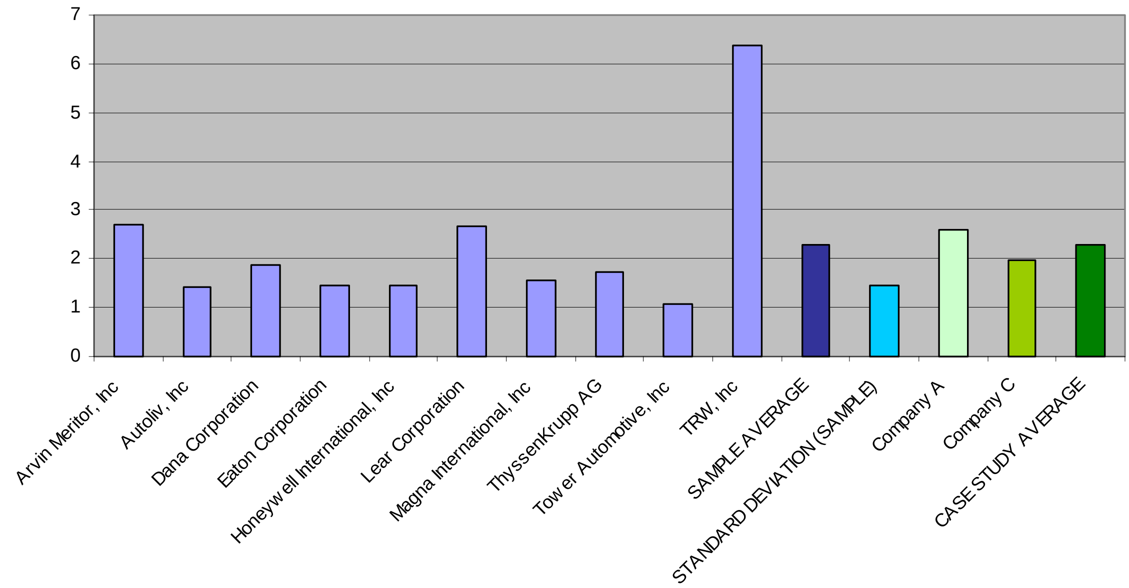
Source: Case Study Data; Hoover's Online (Company Income Statements)

Figure 12 - Net Profit Margin of the Case Study Companies and a Sample of Auto Suppliers



Source: Case Study Data; Hoover's Online (Company Income Statements)

Figure 13 - Net Asset Turnover of the Case Study Companies and a Sample of Auto Suppliers



Source: Case Study Data. Hoover's Online (Company Income Statements)

Considering that profitability is best analysed over extended periods of time, the values presented represent an average of three fiscal years.

The comparison of the case studies' ROTA, ROCE and net profit margin with data from a sample of international automotive suppliers reveals above average profitability ratios for the Portuguese companies. This is indicative of an adequate management of the companies' assets and sales revenue.

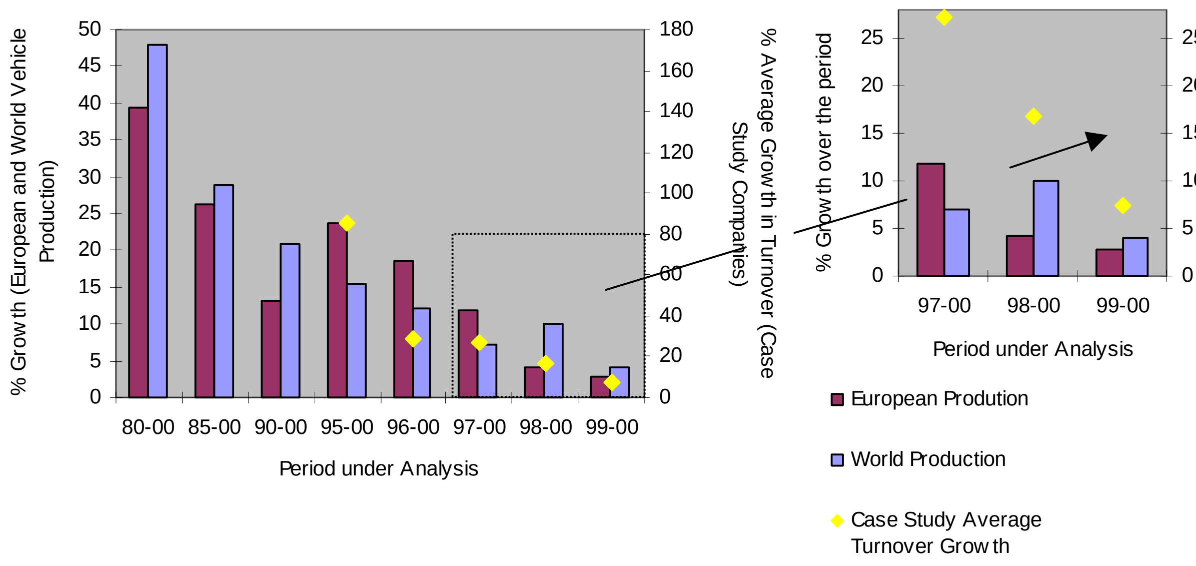
We can thus conclude that during the period under analysis, and according to the ROTA, ROCE, net profit margin and net asset turnover profitability indicators, the Portuguese automotive components case study companies are reasonably profitable. Moreover, these results point towards profitability levels that may in fact be quite higher than the industry average.

4.2.2 Market Share

The small size of the national automotive components companies makes the evaluation of competitiveness through the analysis of absolute market shares an insufficient indicator - in 1997 ten of the largest European automotive suppliers had automotive turnovers over 3257 million dollars (see Table 4) compared to the an average 13 million of the three case study companies. Given the reduced importance of these companies at a global or even European scale, indicators of market performance must not focus on market share *per se* but instead compare the evolution of the companies' market performance with that of its competitors and with the evolution of the final market.

Considering that the companies under analysis have on average 92% of turnover in the automotive industry, market performance can be assessed by comparing the evolution of company turnover with that of the number of vehicles produced in Europe and the World. The analysis of market performance will be complemented by looking at the growth in turnover of a sample of international automotive components suppliers.

Figure 14 – Growth in Vehicle Production and Case Study Companies' Turnover

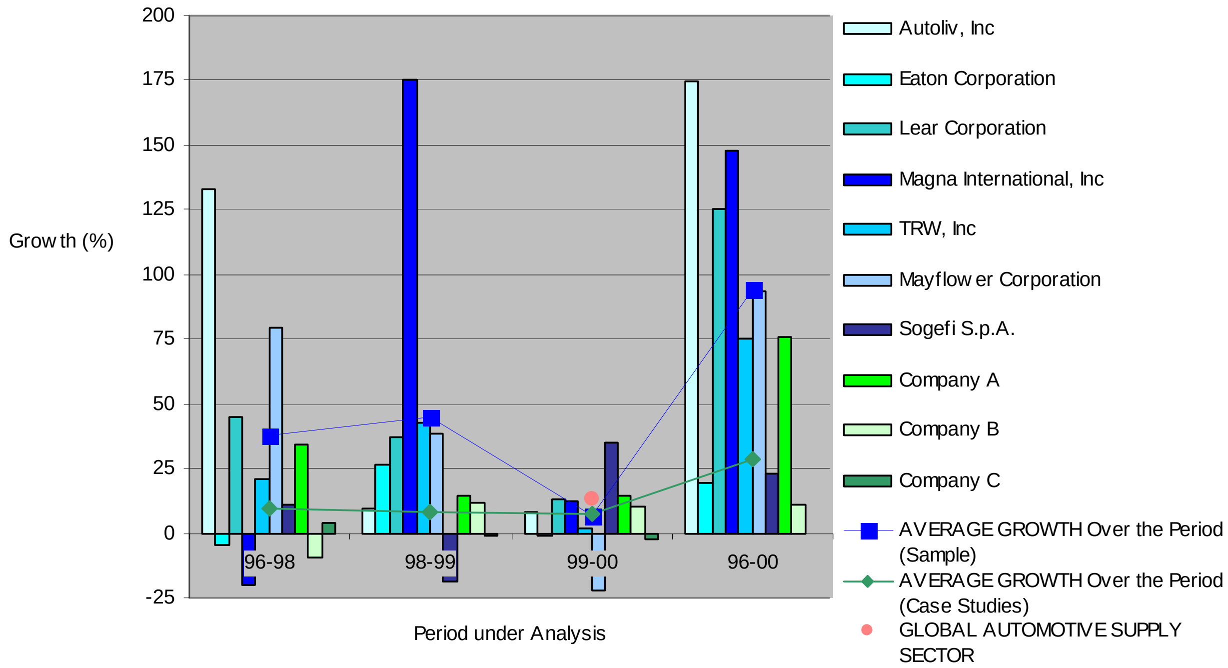


Source: Case Study Company Data; CCFA

The results point towards the case study companies' turnover growth exceeding the rate of growth of vehicle production, both in Europe and in the World. Notwithstanding these values, the increasing levels of outsourcing by OEMs are leading to an overall growth of the components industry that exceeds the growth in production of the final product - the vehicle.

Due to, on the one hand, the heterogeneity of each companies' product portfolio and consequent difficulty in identifying competitors, and the unavailability of data pertaining to such companies, on the other, turnover growth of the case study companies will be compared with that of a set of international components companies. These companies had turnovers ranging from 635 million to 17231 million dollars in 2000.

Figure 15 – Growth in Turnover of a Sample of Suppliers and in the Case Study Companies



Sources: Case Study Company Data; CLEPA; Hoover's Online (Company Income Statements); Company Annual Reports; EIU

The substantial growth that has characterised the automotive components industry at an international level - the global market size of the automotive supply sector rose from 1109 billion Euro in 1999 to 1254 in 2000, a growth of approximately 13% (CLEPA, 2001) - seems to have had a smaller impact on these three companies in particular. Indeed Company C has actually experienced a slight reduction in turnover between 1996 and 2000.

As such, notwithstanding the reasonable growth in turnover of two of the case study companies, this growth is substantially weaker than that of other companies in the same industry. This can be interpreted as a loss of competitiveness in relation to their competitors, which have capitalise on some of the opportunities which have resulted from the restructuring of the automotive industry and the increasing level of outsourcing by OEMs.

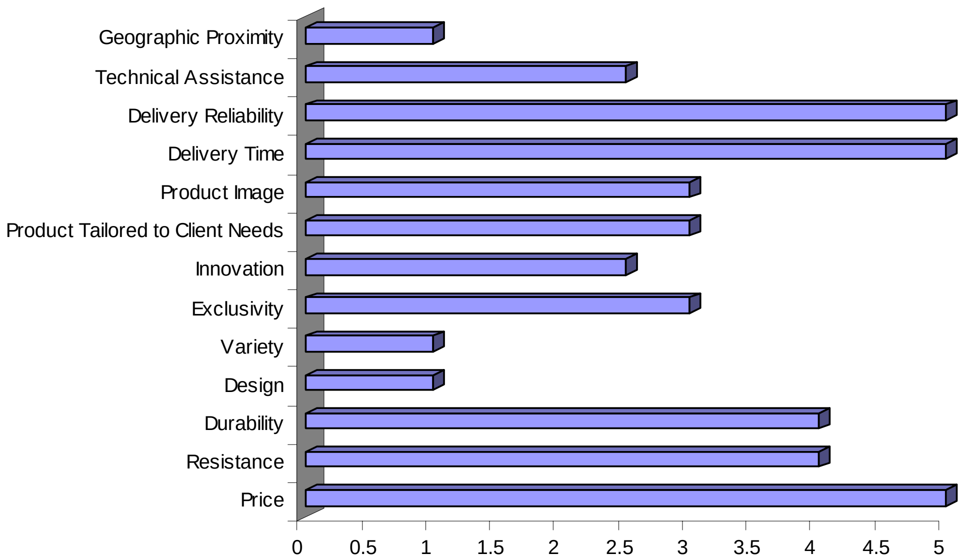
One of the explanations for the slower growth rates of the Portuguese case study companies may be the type of growth strategies which have been used. While Portuguese companies have based their growth on developing internal competencies and capabilities, foreign competitors have complemented this strategy with mergers and acquisitions. In an environment characterised by OEMs demanding constant reduction in unit costs, systems design and production capabilities, and global reach, internal growth is often an insufficient strategy for responding to these market solicitations.

4.2.3 Product Attractiveness

The general tendencies in the automotive industry described in 2.1 impact companies in distinct manners according to their characteristics and that of the environment in which they operate. One of the forms by which the companies become aware of the impact on their specific business is through the everyday contact with evolving client expectations.

In order to identify the characteristics that are valued by the case study companies' clients, the firms were asked to evaluate the importance attributed, by their clients, to a specific set of predefined factors. The importance of these factors was ranked according to a scale of 1 to 5 where 1 represents of no significance and 5 very important.

Figure 16 - Portuguese Components Industry Characteristics Valued by their Clients



These results point towards price, delivery time and reliability, quality (resistance and durability) and product tailoring to client needs as the four most important characteristics value by the supplier's clients.

As previously mentioned, these factors are highly specific to the Portuguese reality, and reveal the current level of development of the industry. Due to these companies' strong focus on the development of manufacturing competencies and capabilities, and the limited efforts made in the acquisition of product design and development capabilities, it is not surprising that significant emphasis is still on price, quality, and delivery time and reliability. In more developed markets, the importance of these factors is supplanted by other factors such as design, development and innovation capabilities since quality, and delivery time and reliability are considered given facts.

In the commodities market, quality, delivery time and reliability are unequivocally defined by OEMs and cannot be seen as variables that define a company's competitiveness, but instead as a prerequisite for doing business in the original equipment market.

Consequently, product attractiveness is defined mainly by cost, and the remaining factors essentially constitute restrictions, imposed by the clients, on the company's outputs. Within this context, the above factors are relevant to the analysis in the sense that they contribute to the primary characteristic valued by the clients – cost.

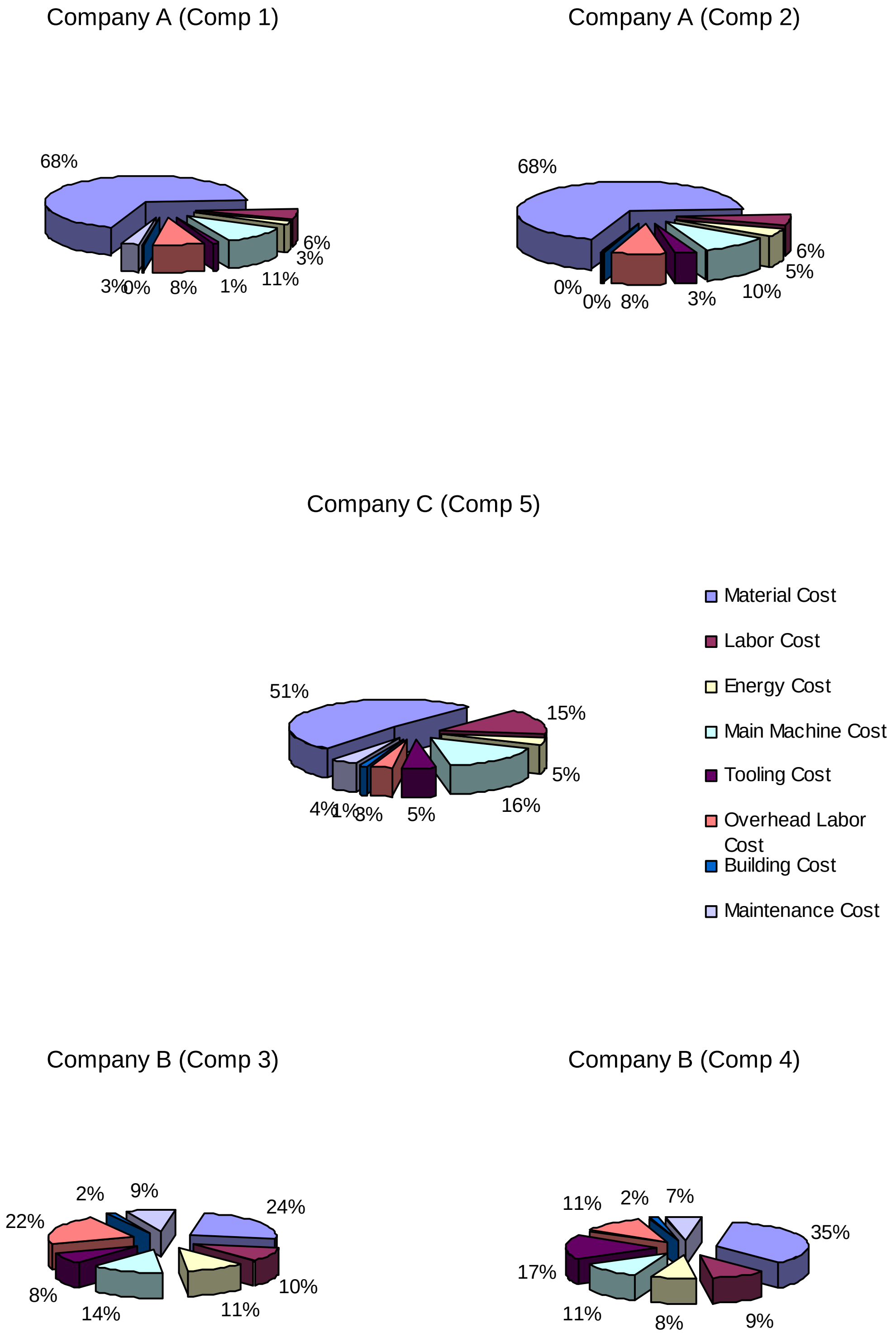
4.2.3.1 Cost

As previously seen, the cost of a product or service can be defined as the result of the acquisition cost of the inputs and of the efficiency with which they are used to manufacture the desired outputs. The analysis of cost as the main product attribute will therefore be made in accordance with these two factors. But before proceeding with these analyses, an in-depth look at the cost structure of the components is essential.

Cost Breakdown by Input

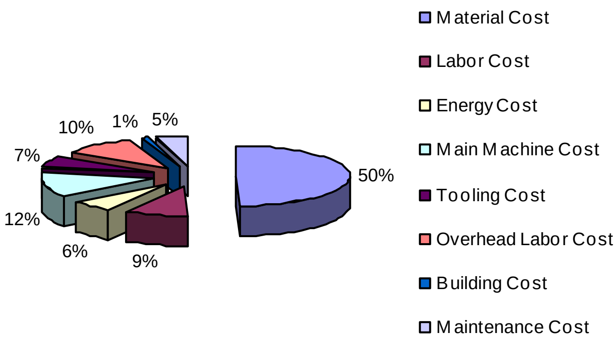
According to the cost breakdown presented in the following figures, the main cost factor for the components under analysis pertains to raw materials. In fact, because the added value of the products is relatively small, the cost of the raw materials accounts for between 24% and 69% of the overall cost.

Figure 17 (a-e) - Cost Breakdown for All the Components



Although all the components analysed are non-visible interior parts, Comp 4, manufactured by Company B, corresponds to a bracket for attaching non-structural electric and electronic components and therefore has lower levels of raw material (steel) incorporation when compared to the structural components of the remaining two companies. In average terms we can identify the following cost structure for the five components:

Figure 18 - Cost Breakdown - All Components (Average)



Notwithstanding the small size of the sample in terms of the number of companies and components analysed, similar cost structures can be identified for components manufactured in the same company. This may be the result of some specialisation, by the companies, on products with specific characteristics or that companies tend to adopt a specific manufacturing strategy, which they then try to apply to as many products as possible.

The first hypothesis does not imply that products are necessarily geometrically alike (Company A products differ substantially from each other in geometrical terms), but that the nature and level of utilisation of the inputs - processes and resources - is similar. The fact that the two Company A products are fabricated according to very distinct processes (e.g. transfer vs. tandem press stamping and roller vs. spot welding) and still present very similar cost structures, seems to suggest that Company A may be focusing its activities on products with similar level of utilisation of the different inputs.

In the case of companies with a more limited scope of competencies and capabilities, product specialisation may not even be a choice. The company, therefore, selects the products it manufactures based on its passed experience in the manufacture of a limited number of products. These products may share common characteristics in terms of the thickness of the sheet metal used, complexity, and size. Given the companies past experience with that type of product, the different alternatives available for its manufacturing are easily identified.

A company that has a broader scope of competencies and capabilities is equally limited by these characteristics, but is able to take on a wider variety of product types. Because products differ substantially from each other, this selection only constitutes the first step in deciding whether a product can be manufactured by the company or not. This criterion is then complemented with a more in-depth analysis of the component's characteristics so as to establish whether the manufacture of the component is economically viable. Ultimately, the choice will be based on the cross-analysis of component and company characteristics through which the firm will identify possible competitive advantages, in relation to its competitors, in manufacturing that specific product. For example, the significant contribution of raw materials to cost in Company A, may be the result of an advantage in the conditions in which it purchases raw materials.

As to the values obtained with the analysis, on average, direct labour costs account for between 6% and 15% of the overall production cost, while direct and overhead labour together account for between 14% and 32% of costs. The nature of the products manufactured by Company B (more complex products), and therefore of the technologies (these products are not manufactured with progressive dies or on transfer presses), require more labour and are relatively more demanding in terms of process engineering than the structural parts. The reduced life span of Company B products equally contributes to higher indirect costs.

The level of complexity is equally patent in the higher tooling costs associated to Company B products although, since tooling investments are considered fixed costs, these components tend to have higher tooling contributions due to lower production levels.

In what concerns equipment costs these vary between 10% and 16%. As we will see in subsequent analyses, the painting technology is partially responsible for the significant contribution of equipment costs to overall costs.

The costs pertaining to maintenance account for approximately 5% of overall costs. This value reflects the relatively high costs associated to stamping maintenance, namely tool maintenance which is time consuming and requires costly specific equipments.

Cost Breakdown by Process

As can be seen by the analysis of Figure 20, the dominating technology in terms of contribution to cost is stamping with approximately 70% of the total. Assembly, which comprises the fastening and welding operations, and painting, contribute 20% and 10% respectively. The individual company cost breakdowns by process can be seen in Figure 19.

According to INTELI (1999) the internal importance assumed by a technology - in terms of the resources allocated to the technology - and the external relevance of the technology - in terms of client valued product attributes that are conferred by the technology – should ideally be in accordance to the company’s level of competencies in that technology. In what concerns stamping, this equilibrium does in fact exist. That is, on the one hand, stamping is the core technology in these companies and as such the technology in which the companies detain the greatest level of competencies. Moreover, and as previously stated, many of the national companies belonging to this sub-sector evolved from tool manufacturers where the utilisation of the presses used in tool testing was optimised through the production of stamped parts. On the other hand, the product characteristics most valued by clients are component geometry in accordance to their specifications and the absence of wrinkles or jagged edges, etc. These characteristics are primarily the result of the stamping technology, although the performance of stamping in turn, is largely determined by the quality of the stamping tools.

From an internal point-of-view, an equally important conclusion can be drawn in relation to improving the companies' technological performance. That is, stamping is clearly the technology where the potential impact of performance improvements on the overall costs is greater.

Figure 19 (a-e) - Cost Breakdown by Process for All the Components

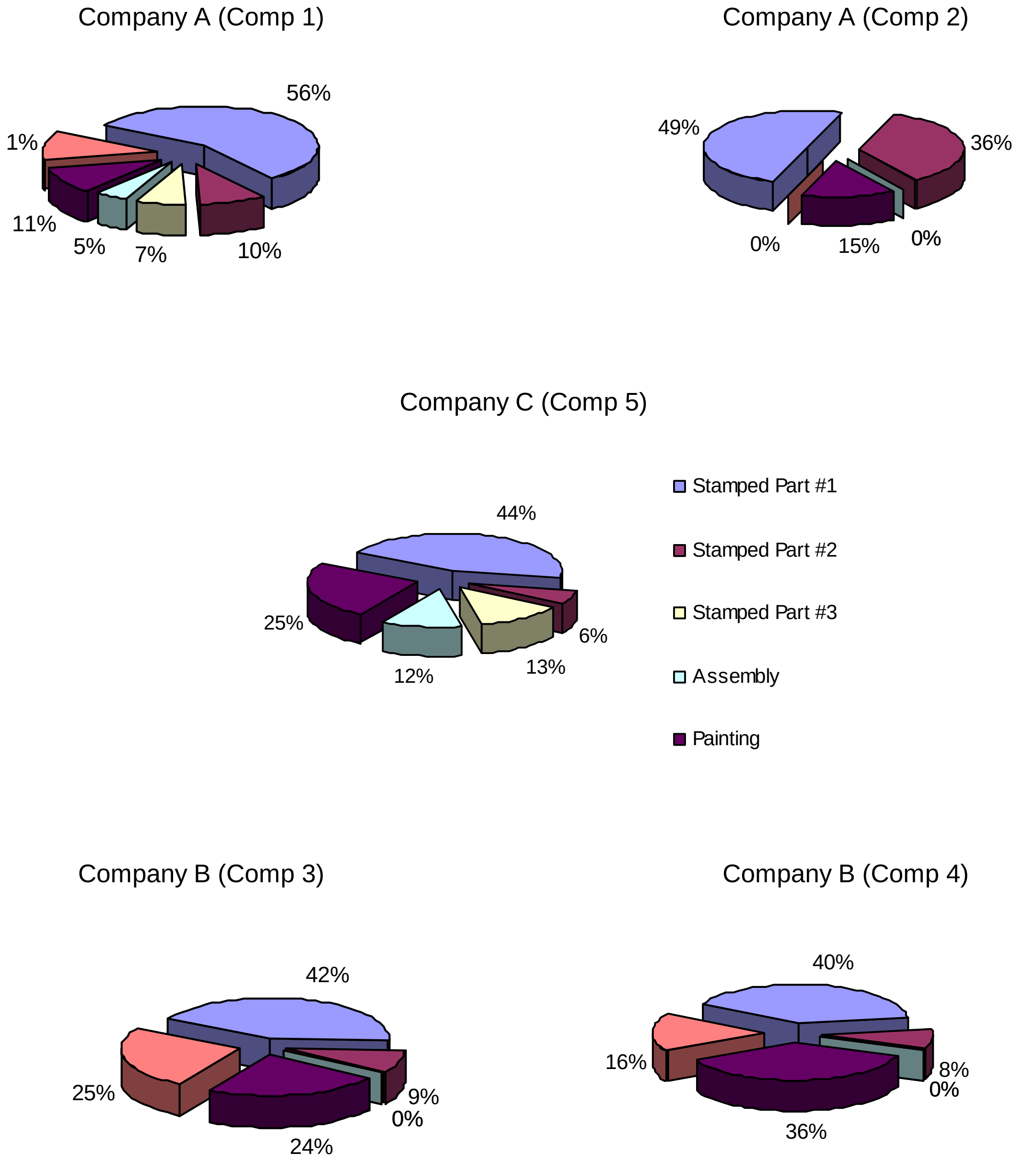
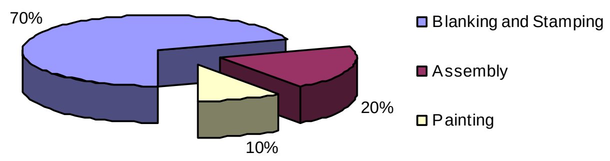


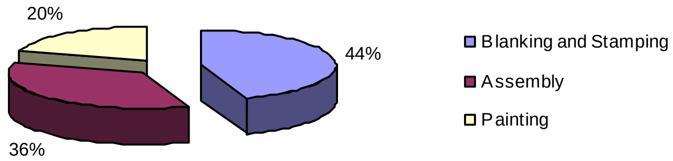
Figure 20 - Cost Breakdown by Process - All Components (Average)



As previously mentioned, similar cost structures can be identified for components manufactured in the same company. This was said to be the possible result of a certain specialisation, in each company, on products that share important characteristics and which lead to similar utilisation of processes and resources. The importance of selecting products that can be efficiently manufactured using the company's technologies is essential (Mckinsey & Co., 1994). A study undertaken by this company positively correlated adequate product choice with good quality performance and good quality performance with profitability. The cost structure of the five components under analysis (Figure 19) seems to support this hypothesis.

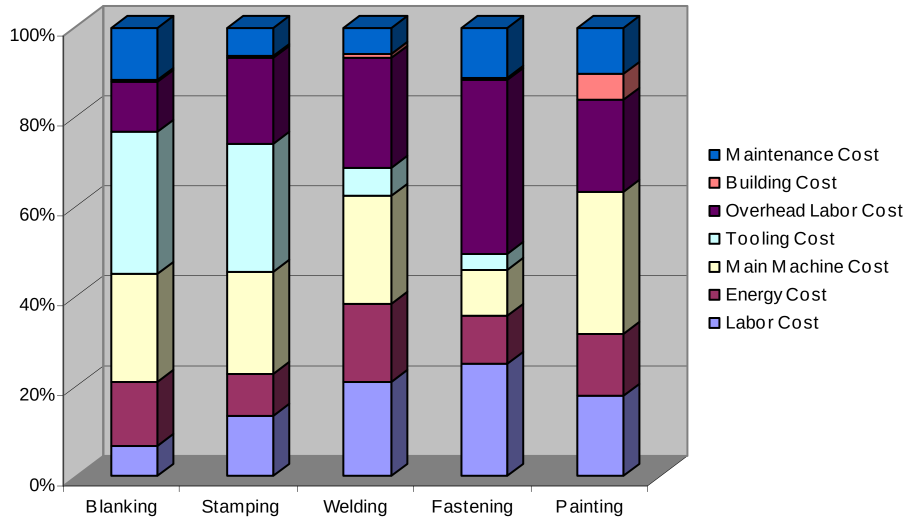
Since the costs incurred in the acquisition of raw materials are accounted for mainly in the blanking and stamping phases of production, an analysis of the contribution of the different technologies to the overall cost, where the costs of the raw materials are excluded, permits a more precise evaluation of the importance of each technology within the companies. As can be seen in Figure 21, stamping remains the most important technology with 44% of the overall costs, followed by assembly (fastening and welding) and painting.

Figure 21 - Cost Breakdown by Process (excluding raw materials) - All Components (Average)



By excluding the cost of raw materials for the above-mentioned reason, it is possible to identify a clear distinction between investment intensive technologies – blanking, stamping and painting - and more labour intensive technologies – the two assembly technologies considered (fastening and welding).

Figure 22 - Cost Breakdown by Process (excluding raw materials) - All Components (Average)



As expected, tooling costs in blanking and stamping account for a significant part of the overall cost (approximately 30% excluding raw materials), value similar to that of equipment costs in painting. For all the technologies under analysis, the contributions of energy and maintenance costs do not vary significantly among technologies. Once again, by identifying the main cost factors for each technology companies should concentrate their improvement efforts in the areas which most contribute to the overall cost.

Besides the external relevance and internal importance of stamping in these companies, the distinct approaches used by the three companies in stamping make a more in-depth analysis of this technology relevant to the remaining analysis

Stamping Process Analysis

Although some new metal forming processes such as hydroforming have been gaining grown in terms of their applicability, stamping is still the most commonly used process. On the other hand, within stamping we can distinguish three sub processes with quite distinct applications, namely in terms of production volumes and the level of initial investments. These sub processes are: tandem press lines in which the parts being stamped are transferred from one press to the next either by automatic means or manually; progressive die in which a press is fed from a continuous metal sheet by use of a decoyler system and where various stamping and blanking operations are carried out in succession; and lastly, transfer press system in which blanks are fed to the press which successively stamps and moves the metal part from one station to the next. In the first and last cases the banks have been pre-cut in a separate process.

Due to the large difference in the stamping cost structure of the products manufactured according to these three stamping techniques we will undertake a more in-depth analysis of three subcomponents.

Exogenous factor conditions and internal performance were varied according to the value on the right of the figure and the effects on cost were measured. Within the same stamping technique, each change in cost is obtained by varying a single factor while the remaining factors remain unchanged. The base cost of the subcomponent (without any change to the factors) corresponds to the value on the far left of the scale.

Figure 23 - Transfer Press Sensitivity Analysis (Company A – Comp. 1 Part 1)

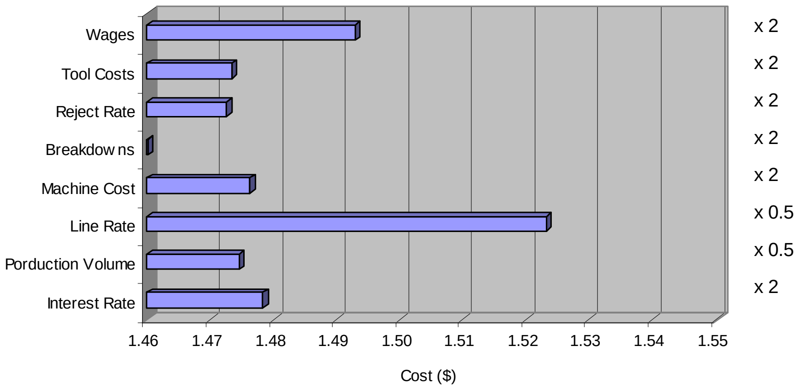


Figure 24 - Tandem Press Line Sensitivity Analysis (Company B – Comp. 4 Part 1)

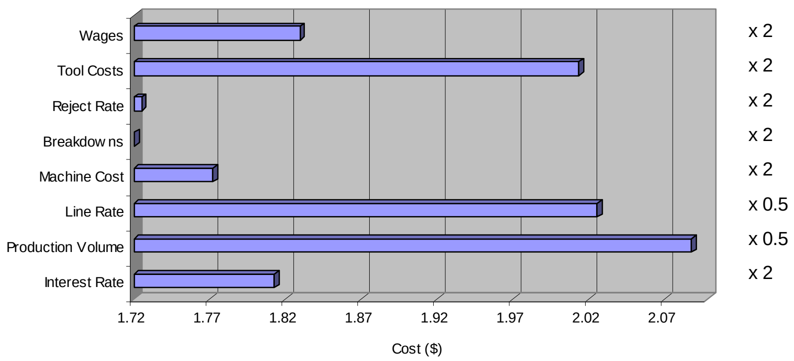
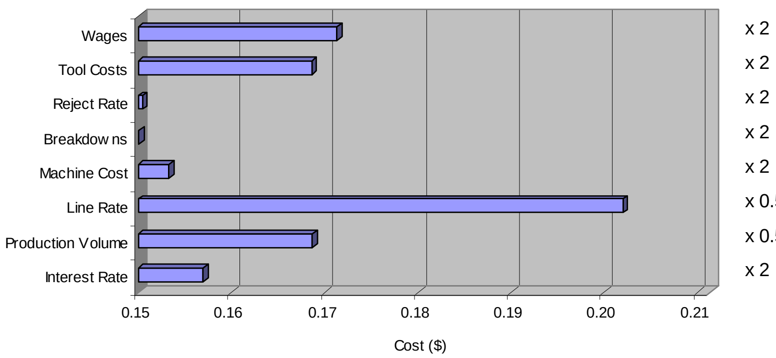


Figure 25 - Progressive Die Sensitivity Analysis (Company B – Comp. 3 Part 2)



Although our aim is to analyse the three different stamping processes and not the components, their influence on the analysis is unavoidable and must therefore equally be taken into consideration.

Let us recapitulate the nature of the three parts and respective cost breakdown before we proceed.

Table 16 - Characteristics of the Parts and Respective Cost Breakdown

	Comp. 1 Part 1	Comp. 4 Part 1	Comp. 3 Part 2
Annual Production Volume	171 2534	140 000	300 000
Weight (kg)	2.079	0.84	0.17
Final Surface Area (sqm)	0.066	0.032	0.051
Level of Complexity	Low/Medium	High	High
Cost Breakdown			
Material Costs	68%	2%	52%
Labour Costs	6%	6%	5%
Energy Costs	3%	21%	11%
Machine Cost	11%	8%	2%
Tooling Costs	1%	48%	13%
Overhead Labour Costs	8%	7%	10%
Building Costs	0%	0%	0%
Maintenance Costs	3%	7%	8%

By analysing the results it is possible to see that variations in line rates assume more or less the same importance irrespective of the stamping process used. Varying line rates impact all time-dependant factors such as labour, tooling, building and machine costs, as throughput per unit of time is altered. Since labour costs are similar for the three parts, maintenance costs are small and equally similar, and building costs are irrelevant, let us focus on tooling and machine costs.

The complexity of Comp. 4 Part 1 leads to significant tooling costs and consequently small variations in tooling costs have a great impact on the overall cost of stamping the part. On the other hand, although the variations in the cost of stamping this part, induced by variations in which machine cost, are significantly smaller, they are still substantially larger than in the case of progressive die and transfer press processes. This is due to the additional equipment costs of undertaking successive stamping operations on different presses instead of using a single transfer press or progressive die, notwithstanding the costs associated to the automation of these two processes which is normally absent in the case of tandem presses, and the higher costs incurred in the acquisition of larger bed size and tonnage press.

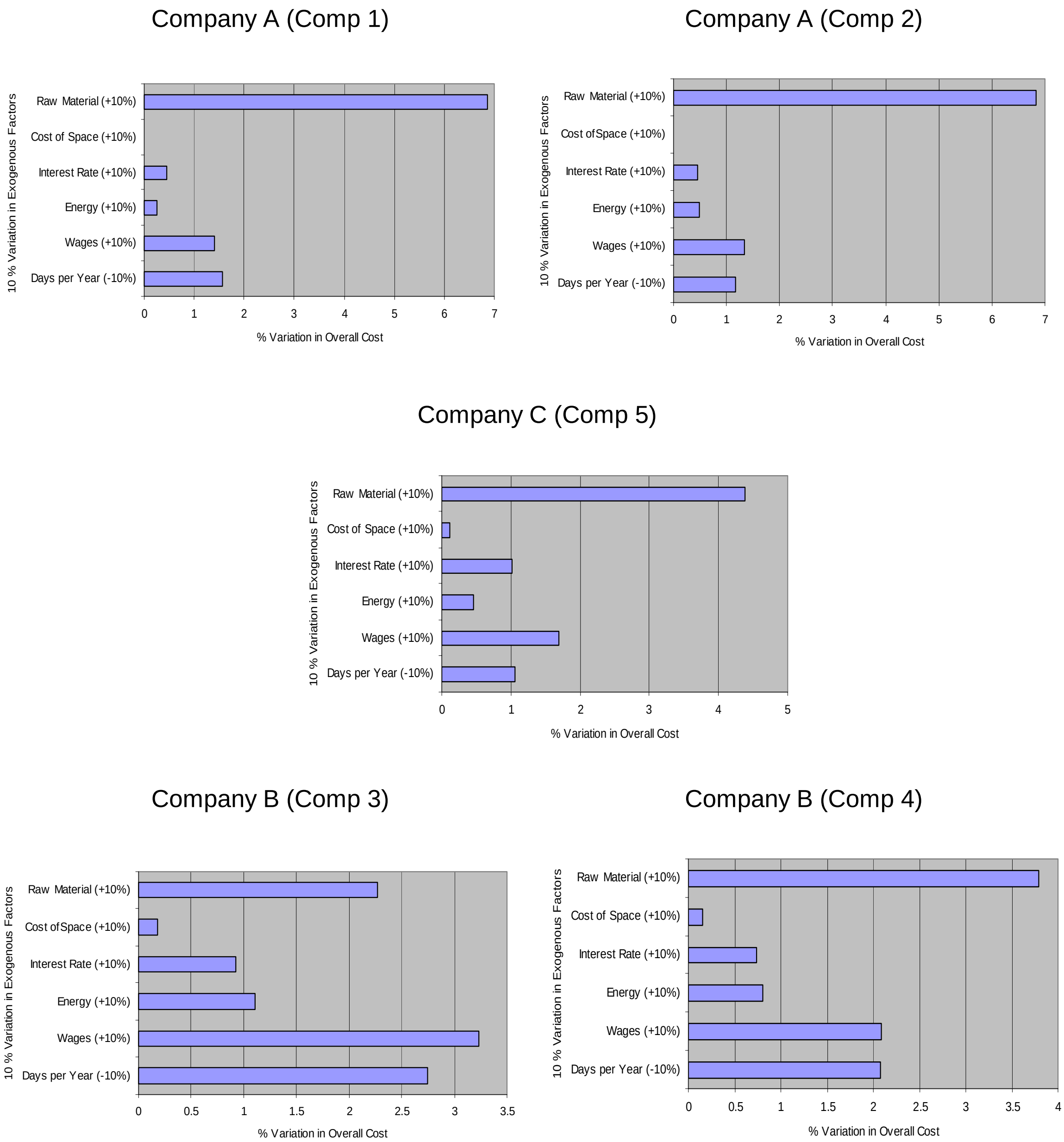
Although the use of tandem presses may account for greater equipment costs, the use of this process has clear benefits in terms of flexibility and investment. That is, since not all processes are carried out sequentially (generally, except in the case of delivery to the client, companies are far from working according to just-in-time principles between processes) and the time each individual press is used is less than that of the other two processes, the level of flexibility of this processes is greater. Moreover, small individual presses are widely available within the companies. This frequently reduces the need to invest in machinery for production of a new component.

In what concerns tooling costs, these do not vary significantly according to the process but are basically determined by the complexity of the part and consequently of the number of stamping operations required by the component – more complex geometries require additional stamping operations which in turn require more stations, or in other words, more tools.

4.2.3.1.1 Cost of Inputs

Besides the companies' individual manufacturing performances, an important part of the overall cost is determined by external factors. So as to measure the influence these factors have on overall cost and the implications resulting from their evolution over time, a 10% variation of these critical factors is considered, always in the sense that it harms the competitive ability of the firms, and the effects on final cost are analysed. The individual results for each company and component are presented in Figure 26 (a-e).

Figure 26 (a-e) - Exogenous Factor Variation for All Components



The results for the three companies and five components analysed reaffirm the cost of raw materials as being a determinant factor. In fact, for Company A a 10% increase in the cost of raw materials produces an rise in overall cost of the two components of approximately 7%. These are in fact the two largest and heaviest components, while for Comp 3 (the smallest and lightest) the variation is only of about 2%. The significant influence on overall cost of raw materials costs puts emphasis on the need for companies to utilise this resources in an optimal manner. This can only be achieved through the introduction of changes to the products and through process performance improvement. The second will be analysed in more detail latter on in this chapter.

Variations made to the remaining factors produce substantially smaller changes in overall cost. Nevertheless, it is quite apparent that wages and working days per year are the second most potentially troublesome factors. In fact, while in relation to the number of working days, no significant changes are expected to occur in the near future, the same cannot be said in relation to the cost of labour. Although slower growth rates are expected during the next years, the current unemployment figures and the competition amongst different industries for the best human resources will continue to induce increases in wages slightly above the inflation rate.

A possible solution to this problem seems to lie in the reduction of the level of manual labour. Although this reduction can be achieved by incrementing the level of automation of some processes, this solution will lead to the partial erosion of the Portuguese companies' competitive positioning, by converging towards a situation in which countries such as Germany are clearly in advantage. As such, the solution seems to lie in establishing of a tradeoff between increasing automation and reducing the number of human resources. Nevertheless, this new equilibrium position requires that a significant investment be made in hiring and training more qualified personnel capable of taking on a wider and more demanding range of tasks. This statement will be complemented in the comparative analysis of fabrication cost associated to the production of these same five components in different countries.

Lastly, a reference to interest rates. For many years the evolution registered in interest rates benefited the Portuguese economy as a whole and these companies in particular, the current tendency is clearly less favourable. Although reasonable cost variations can occur due to changes in interest rates (as demonstrated in e.g. Company C Comp 5), in a context characterised by Portugal's convergence towards EU average interest rates, these changes are no longer exclusive to the Portuguese economy. Nevertheless, because current interest rates in Portugal remain slightly higher than those in most EU member countries and the above mentioned convergence does not necessarily include East European nations, interest rates will continue to play a important role in defining the competitive positioning of companies from different nations.

International Comparison of the Cost of Inputs

In order to better characterise the Portuguese companies' main competitive advantages which derive from specific national exogenous factors, a comparative analysis, based on the evaluation of production costs in various counties, is undertaken. This will be achieved by varying the model's external factor inputs in accordance with each country's reality. The three countries considered in this analysis were chosen in accordance with two distinct and separate objectives. The first two countries represent markets supplied by the three companies. In these markets, the Portuguese companies have to have distinct advantages in relation to the domestic competitors. The Czech Republic was chosen due to its geographical proximity to the main automotive assembly markets and as an example of a developing nation with competitive advantages similar to that of Portugal.

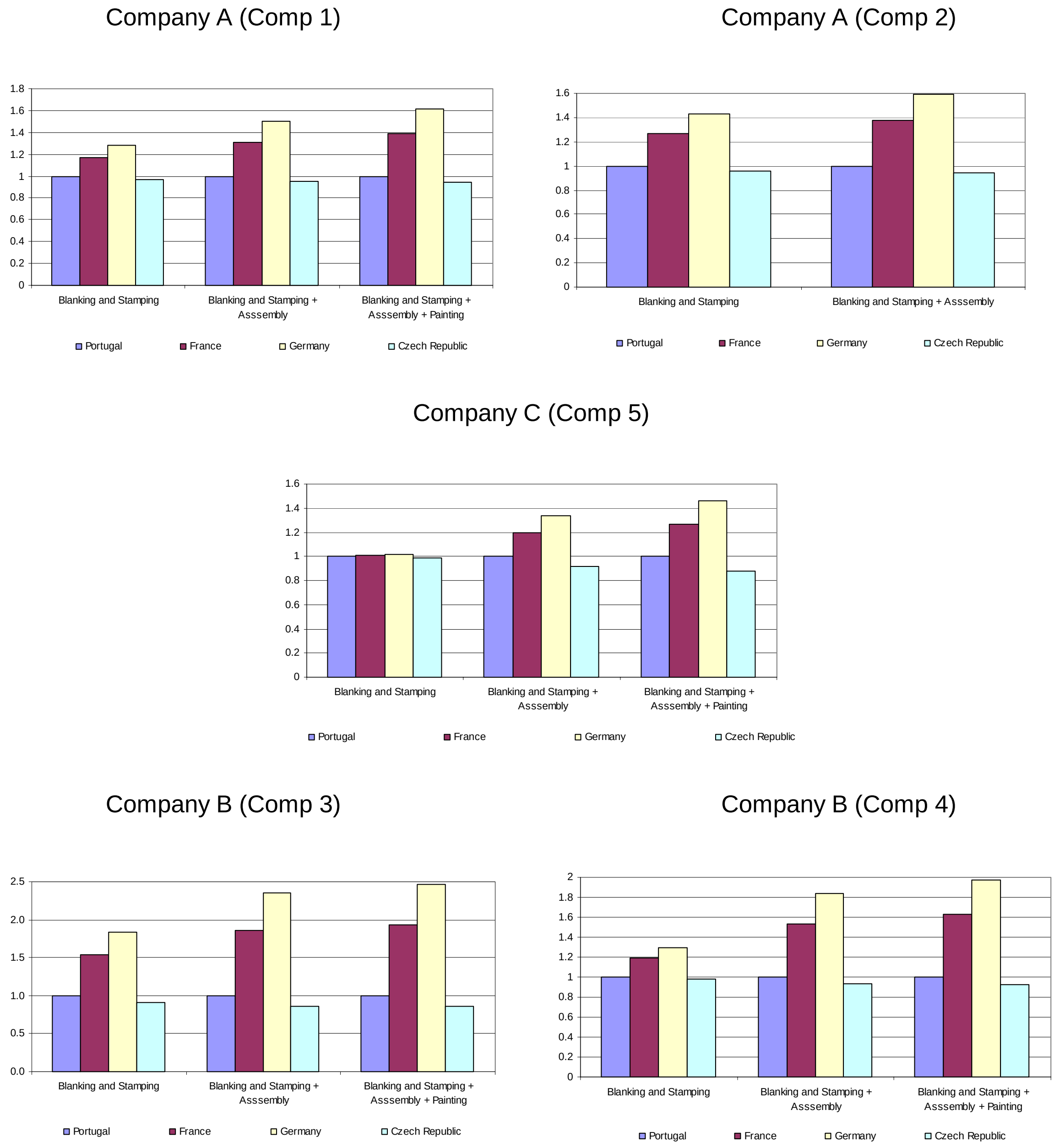
This analysis varies the relevant external factors according to the country's specific conditions but does not consider any performance differences resulting from operations in distinct environments. The various factors that contribute towards defining manufacturing performance and the difficulties in collecting the data required on average manufacturing performances in the various countries, make attributing different performance levels, to the four countries under analysis, extremely difficult. Considering that a firm's competitiveness is partially determined by its ability to adequately exploit exogenous factor conditions, the results obtained with the following analysis will be complemented with comments based on the general perception of manufacturing performance differences among the four countries. Therefore, the results presented in Figure 27 can be seen as the costs incurred if firms with the exact same characteristics as the Portuguese case study companies were to manufacture these components in France, Germany or the Czech Republic.

The five external factors considered are the number of working days per year, level of wages paid, cost of energy, interest rates, and cost of building space. The cost of raw materials was not considered since it does not vary substantially among the countries analysed.

Table 17 - Exogenous Factors Considered in the International Comparison

	Portugal	France	Germany	Czech Republic
Days/year	230	240	240	260
Wages (PTE)	920	3402	4914	567
Energy Costs (PTE/kwh)	9.86	15.12	15.12	9.86
Interest Rates (%)	8%	6%	6%	10%
Building Costs ($/square m)	300	1 500	1 500	500

Figure 27 (a–e) - International Comparison for All Components



As can be seen from the analysis of these three companies' products, an adequate exploitation of the Portuguese exogenous factors, based on the right choices made in relation to the type of manufacturing process and the nature of the components produced, is generically present. That is, companies have, to a reasonable extent, succeeded in adjusting their products and manufacturing technologies to the conditions imposed by the environment. But, notwithstanding the clear advantage in relation to France and Germany, in the case of the Czech Republic there is a slight cost disadvantage. In fact, all five components could be produced at a lower cost with the same manufacturing process and the Czech Republic's exogenous factors, even though it should be expected that the processes used by Czech companies be in closer accordance to their specific national exogenous factor advantages and less to that of Portugal.

The only process in which the Portuguese exogenous factors yield competitive costs is painting where there is no substantial cost difference. Considering the significant investments required for establishing a painting line and the large area occupied by this technology, this may be the combined result of the lower cost of space and of interest rates practiced in Portugal.

Considering the geographical proximity of some East European countries to the main European automotive markets and an eventual cost advantage in relation to the Portuguese companies, there are two possible explanations for the presence of the case study companies in these markets with these products. The first has to do with a possible lack of competencies and/or capabilities in the firms from East European countries. This may lead to some difficulties in penetrating into foreign markets. The second possibility is related to the importance of other factors besides price. Although price assumes great importance in the client's purchasing decision, other factors are equally important. If the firms from Eastern Europe are unable to perform in accordance with these factors, competitive prices alone will not guarantee a place in today's automotive industry. This hypothesis is confirmed by Veloso *et al.* (2000), who states that firms in the Iberian Peninsula are better endowed than their Eastern European counterparts in terms of know-how and experience.

The analysis undertaken for the Czech Republic must be seen as an example of kind of advantage companies in East European countries may have in the production of this type of components. In the medium to long term, it is expected that the domestic companies evolve in a similar manner to that of the Portuguese companies, hereby positioning themselves as second or third tier suppliers. In doing so, these companies will displace firms from countries with comparatively unfavourable exogenous conditions, market positions essentially based on the supply of labour intensive products and the use of price as their main competitive argument.

Labour/Automation Input Analysis

The favourable cost of labour in Portugal (see Table 18) has led companies to rely heavily on what Prais (1995) would designate as *mechanisation*. According to this author, the technological progress in industry initially result in *mechanisation*, that is machines performing tasks which had previously been performed by skilled craftspeople. This created a need for unskilled people to operate and feed the machines. With further progress, technology has increasingly led to automation, where processes are performed solely by machines. Consequently, many unskilled jobs have been eliminated and the need for more skilled workers, who can monitor, improve and adjust the production process, has increased.

Table 18 - International Comparison of Labour Costs in Manufacturing (1998)

Country	Hourly Direct Pay Labour Cost (US $)	Hourly Compensation Costs (US $)
USA	14.77	18.66
Canada	13.09	15.60
Mexico	1.64	1.84
Japan	15.36	18.29
Taiwan	4.79	5.27
Belgium	16.65	23.20
France	12.52	18.28
Netherlands	16.35	21.17
Germany	20.04	26.76
Greece	6.93	8.91
Italy	12.08	17.11
Portugal	**4.20**	**5.48**
Spain	9.04	12.14
United Kingdom	14.31	16.43

Source: U.S. Department of Labor, Bureau of Labor Statistics, September 2000

Only recently have Portuguese firms begun investing in more automated machinery that require limited human intervention in terms of their normal production cycle and specialised skills in programming and monitoring.

Notwithstanding this tendency, the Portuguese companies' competitiveness, which is still partially based on the lower level of wages, may be eroded if an equilibrium solution in terms of the level of automation is not struck.

Considering that most West European countries have, on average, 2% lower interest rates (cost of capital) and higher wages, the following analysis will seek to identify an equilibrium position in which the overall cost remains unchanged, the cost of capital is reduced by 2% and labour costs are varied accordingly. A similar analysis will equally be carried out for equipment inputs. The following results where obtained for two of the components analysed.

Table 19 - Cost of Labour vs. Cost of Capital

Maintaining the Overall Cost Unchanged with a 2% reduction in Interest Rates	Company A (Comp 1)	Company C (Comp 5)
Possible Increase in the Cost of Labour	9%	8.5%
Possible Increase in Equipment Inputs	25%	105%

These results indicate that lowering interest rates to West European average levels yields approximately 9% possible labour cost increases while maintaining overall cost unchanged. Considering that the differences in salaries between Portugal and the EU average are still substantial, this margin is in fact very slim. On the other hand, a 2% reduction in interest rates makes substantial investments possible (the real difference is even larger since the amount of labour input remained unchanged notwithstanding the investments made in equipment and the expected favourable impact on productivity). This result seems to suggest that the deceasing trend in interest rates, as the Portuguese economy is increasingly integrated within the EU, opens up good prospects for investment in more capital-intensive processes.

The present levels of automation are therefore favourable to an overall increase in the level of automation as long as this change is accompanied by a reduction in labour costs, or/and productivity increase, or a reduction in interest rates. Nevertheless, if interest rates where to remain above EU average and salaries short of that of competing European countries, it is obvious that the Portuguese competitive positioning must continue to be based on comparatively less automated processes.

4.2.3.1.2 Productivity

While the basic principal of assessing productivity through the measurement of outputs relative to inputs is common to all productivity indicators, due to, on the one hand, the need to guarantee uniformity of criteria and, on the other, difficulties in accessing comparable data, comparisons between firms are not always established at the most relevant level. Instead they are made at the level where these two conditions are simultaneously met.

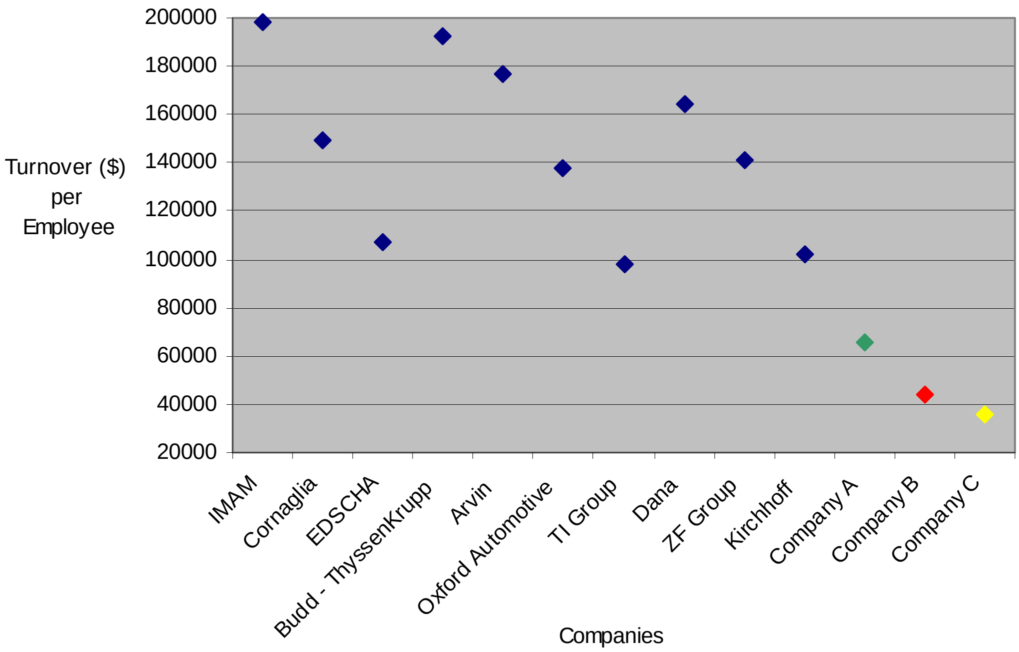
If evaluating productivity by measuring value added per employee initially seemed to be the most adequate solution because it took into account the varying levels of value outsourced within the automotive industry, the lack of consistent data meant that productivity would have to analysed according to a ratio of company turnover per employee.

Simultaneously, the relevance of evaluating productivity through the analysis of a single input – in this case labour – depends on the contribution of that specific input towards overall cost. This condition is in fact met since previous analyses have shown that direct and indirect labour account for approximately 19% of overall costs Figure 18. Considering that raw material are responsible for 50% of overall costs, and that the price at which they are acquired is only partially determined by company actions, labour is the major cost factor which depends on the company's performance. Moreover, given the present characteristics of the three companies under analysis, labour is an indispensable input to the vast majority of processes that rely heavily on the past experience of the workforce.

As can be seen in Figure 28, these companies' labour productivity (measured in terms of turnover per employee) is significantly lower than that of other foreign firms in similar areas of activity. Although some of the companies in this sample supply higher value added stamping-based products that may bias the analysis, others have product portfolios that closely resemble that of three Portuguese companies. Nevertheless, as the previous analysis has demonstrated, these differences can in part be attributed to the favourable costs of labour and the unfavourable cost of capital in Portugal when compared to other countries. This situation, that is not specific to these companies but is contextual, leads to the utilisation of more labour-intensive solutions, where workers often undertake tasks that could be executed by machines.

According to Rodrik (1999), who analysed the relationship between labour productivity, political freedoms and wages, labour productivity is the major determinant of wages. Rodrik concluded that value added per worker explains 80-90% of the cross-national variation in manufacturing wages. Since wages in Portugal are significantly lower than in the countries in which these companies have their operations, it should be expected that productivity levels in the case study companies be substantially lower. Notwithstanding the differences among countries in terms of the investment in machinery versus the use of labour, the gap in labour productivity is widely recognised by company CEOs, which consider the level of qualification of the human resources as the main factor impairing greater convergence to international standards.

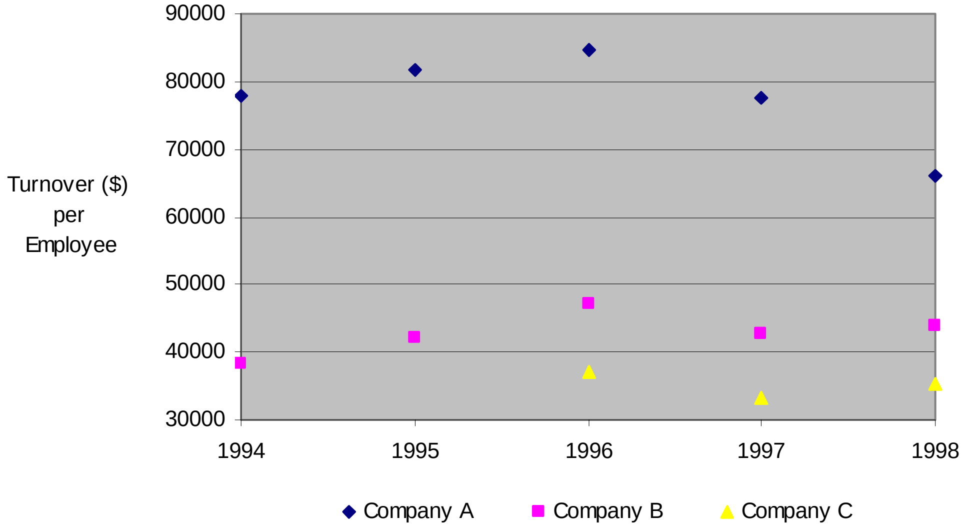
Figure 28 - International Comparison of Turnover per Employee



Source: Various Sources of Company Data; Case Study Company Data

On the other hand, the growth rate in labour productivity in these companies is not very substantial (Figure 29). Considering, on the one hand, that the difference in labour costs between Portugal and other EU countries will probably continue to decrease, and, on the other, the significant use of labour in the companies' operations, substantial gains in labour productivity must be sought if companies are to remain price competitive in future.

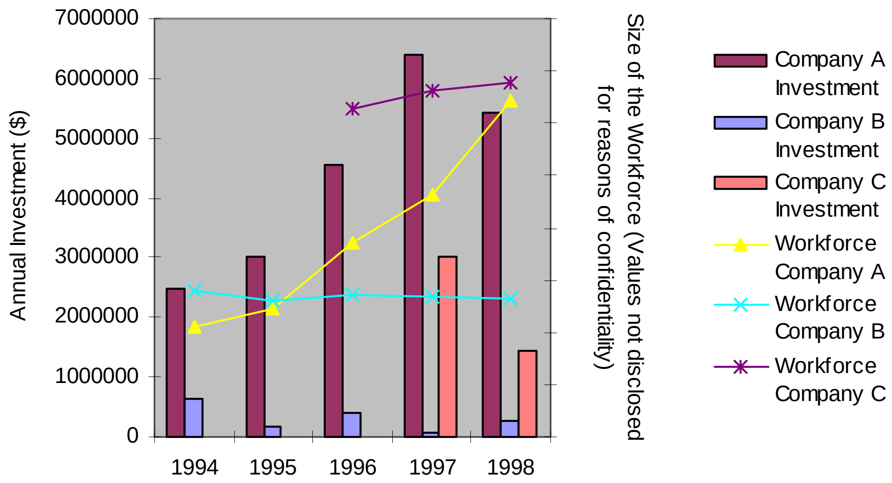
Figure 29 - Labour Productivity of the Case Study Enterprises



Interestingly, this evolution has occurred in a period in which, on average, substantial growth has occurred in terms of turnover and the size of the workforce Figure 30.

By comparing the evolution registered in the three companies in terms of labour productivity, a somewhat common pattern can be identified. This may be the result of similar growth strategies being adopted amongst the companies, which in turn could be a consequence of similar readings of the main factors that shape these decisions.

Figure 30 - Investment Level vs. Workforce



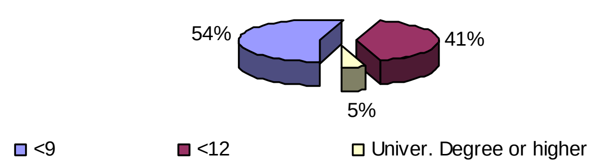
At the firm level, the stability may be the result of the adoption of clear growth strategies that are adhered to over time. For two of the three companies analysed, present development strategies seem to be based on increasing the level of investment at a rate far greater than that of the workforce. The fact that disembodied investment accounts for less than 1% of overall investment confirms previous statements made in relation to the emphasis given to the acquisition of physical assets. Consequently, as companies realise that the continuing rise in the cost of labour has a significant impact on the profitability of their operations, they are increasingly investing in more capital-intensive processes. In practical terms, this may mean substituting tandem presses for transfer or progressive die presses, or directly replacing welders by robots.

Notwithstanding these efforts, the stabilisation of labour productivity seems to indicate, among other things, that the present pattern of growth may lead to a loss in competitiveness in the short term. Indeed, where as in the recent past, attaining critical mass in manufacturing was of the utmost importance, today's challenges are quite different. Presently, besides manufacturing capacity, companies have to constantly improve their performance in core activities and/or broaden the scope of their operations, in order to remain competitive. Companies need to take decisive steps towards higher value added products and services. If size is a critical factor in the sense that the investments required for pursuing this strategy are significant, then companies may have to consider other forms of growth. The present characteristics of the automotive industry are extremely unfavourable to slow growth strategies based on the development of internal competencies and capabilities. Mergers, acquisitions, and co-operation among firms must clearly be seen as the only viable means of achieving rapid growth.

While TCM will help shed some light on the reasons behind these figures, the underlying issue may in fact be the skill level of the workforce. Case studies undertaken by Prais (1995) have demonstrated that superior workforce skills are the major source of competitive advantage. The results obtained by this author point towards training, which seeks to upgrade the technical skills of the workforce, while supplying workers with more general skills which enable them to adapt to future tasks, has having a significant impact on productivity. In a similar study, Bartel (1994) analysed 155 companies in terms of productivity and formal training. He concluded that the productivity of the companies that had implemented training programs had risen by more than 18% in a three-year period, whereas the companies, which had not implemented training over the same period, had only achieved small improvements in productivity.

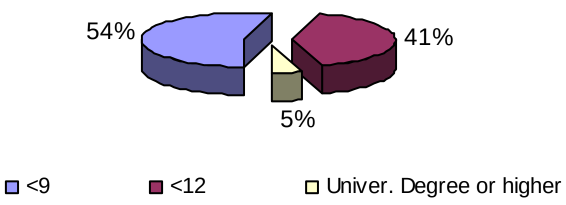
Considering that formal training and productivity are in fact positively correlated, the low number of years of school of the workforce in the companies studied may in fact partially explain the above productivity figures (Figure 31). These values point towards a low number of workers with university degrees and the predominance of workers with less than nine years of school.

Figure 31 - Average Number of School Years of the Workforces



When compared to the figures pertaining to the overall workforce, the number of school years of the workers in the production departments is slightly lower. Moreover, the average percentage of workers with an university degree or higher falls to 2% (Figure 32). Considering that the main competencies and capabilities of these companies are in manufacturing, this situation raises the question of whether these companies' priorities in terms of implementing training programs and recruiting skilled workers are adequately responding to company needs.

Figure 32 - Average Number of School Years of the Human Resources in Production



Given the low number of years of school of the workforce, above-normal investments have to be made in training by the companies. As such, the number of annual hours of training per employee in these companies is reasonable (Figure 33 and Figure 34)[2] when compared to data presented by O'Connell (1999) from the "International Adult Literacy Survey" (IALS). This comparative survey of demonstrated literacy skills among adults in different countries puts forth average values that are slightly higher than those registered in the case study companies. In the 11 OECD countries surveyed, the average number of training hours per employed person was 53.8. Considering that the participation in adult education and training in the 16-65-age group population in Portugal was estimated at 14.2%, these figures confirm the firm commitment of the companies to the training of their employees.

Figure 33 - Average Training Hours per Year – Company B

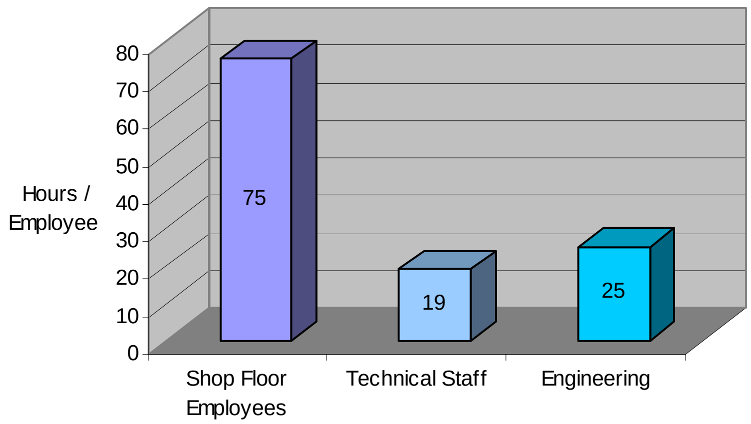
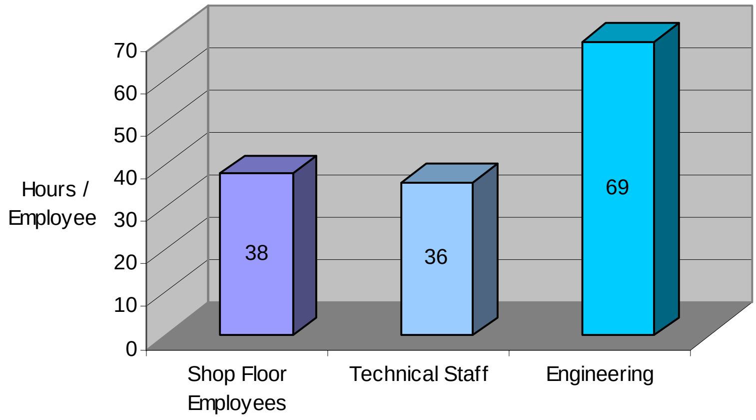


Figure 34 - Average Training Hours per Year – Company C

[2] No data was available for analysis from Company A



As can be seen by analysing these two graphs, although different priorities in terms of the development of human resources were present during the year that preceded this study, the overall efforts in training are reasonably high. Again, from the point of view of the companies' CEOs, substantial efforts are made in training because the formal education of the workforce by the Education System fails to respond to companies' needs.

This assessment may not be far from corresponding to present reality as recent international studies have shown. The "Performance Assessment in IEA's Third International Mathematics and Science Study (TIMMS)" (Harmon *et al.*, 1997) placed Portugal in 17th position in a sample of 19 countries[3] in terms of eighth grade student achievement in science and mathematics. Portuguese students only outperformed their counterparts from Colombia and Cyprus and scored behind students from countries such as Romania, Slovenia and Iran. Since more than half the workforce in these companies has less than nine years of school, this is the reality companies have to deal with.

On the other hand, the same OECD study reveals significant deficiencies in all professional categories, including managers. The low level of qualification of the human resources in the lower hierarchy levels in the companies must not be seen as the sole cause of some of the deficiencies occurring in these enterprises, but rather as a piece of a more complex puzzle in which the skills of the companies' CEOs and managers play an equally important role.

This situation has consequences on the level at which training must primarily focus on. Hashimoto (1994) and Berg (1994) found that the relatively poor general skills acquired by American workers before they are employed meant that employer-sponsored training takes place at a lower level than that of workers in Germany and Japan. As a result, added attention must be given to leveraging the general skills of the workforce before investments are made in specific training. International studies (Hayton *et al.*, 1996) have shown that a significant part of training is directed towards supporting workplace change and not to improving the general skills of the workforce. In situations in which the general qualifications of the employees are weak, this may not be an adequate long-term solution as efforts made in specific training may be limited in terms of effectiveness.

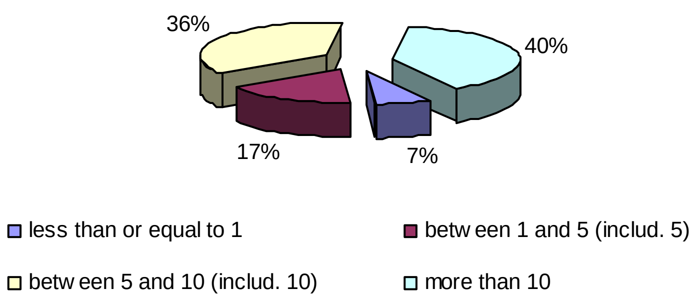
[3] Countries included in the sample: Singapore, Switzerland, Sweden, Scotland, Norway, Czech Republic, Canada, New Zealand, Spain, Iran, Portugal, Cyprus, Australia, England, Netherlands, United States, Colombia, Romania and Slovenia

As previously mentioned, low productivity levels are considered by Prais (1995) and Bartel (1994) to be a consequence of the weak training and adult education levels. Considering that significant efforts have been in the acquisition of physical assets during the last years and that these investments have not been accompanied by equal gains in labour productivity, the underlying issues may in fact be the qualification level of the workforce and a possible misinterpretation of its impact on the success of the investments made.

In the past, investments have largely been based on increasing the level of *mechanisation* (see point 4.2.3.1.1), hereby avoiding the move to technologies that demand higher skill levels, and less on significantly impacting the qualification levels of the workforce. According to Lawrence and Slaughter (1993), who analysed the consistent substitution of unskilled by skilled labour in American firms during the 1980s, this pattern of behaviour by firms is only cost-effective if accompanied by technological change making skilled labour relatively more productive. As such, two main factors may be contributing to the weak productivity levels; the low base of qualification of the human resources, and investments in physical assets that are inconsistent with the efforts made in training because they do not lead to the increase in demand for skilled labour.

Considering the reasonable efforts in training and the significant number of years of experience - approximately 11 on average (Figure 35) – the main issue may in fact lie in the nature of the training the workers are being given.

Figure 35 - Average N. of Years of Experience of the Workforce



4.2.3.1.2.1 Management Efficiency

Human Resource Management

The small size of the companies under analysis has a beneficial effect on the number of hierarchy levels. Typically, a company with a workforce of 250 will have four clear hierarchy levels in the production area. These consist in the CEO, department manager of production, supervisor and worker layers. Flattened hierarchies facilitate communication between all hierarchy layers and promote a more proactive participation of employees when communication is complemented with the valorisation of employee opinions by top management in the decision taking process. McKinsey & Co. (1994), in a study that positively correlates quality with economic performance, considers reduced number of hierarchy layers as one of the main organisational factors that determines quality excellence. According to this study, in a sample of companies with an average workforce of 1000 employees, the average number of hierarchy levels in the production area was found to be of 5.3 for the *quality* companies and 6.4 for the *lower quality* companies (see Table 21 for the definition of *quality* and *lower quality* companies). Although, on average, the companies in the sample are substantially larger in size than the Portuguese enterprises, the results point towards the existence of flattened hierarchies in the Portuguese companies.

Notwithstanding the flattened organisational structure of the Portuguese companies, the level of interaction between the different hierarchy layers is quite limited. An employee in a specific hierarchy level, typically, only has access to the layers immediately under and above his own level. As such, shop floor workers will interact almost exclusively with the supervisor and will have very limited access to the department manager. The interaction between these two hierarchy levels only occurs when issues pertaining to the individual employee have to be addressed.

On the other hand, insufficient relevance is given by CEOs to maintaining a motivated workforce. This may be the combined result of, among other factors, an excessive focus on output, the predominance of short-term goals over medium and long-term objectives, the low educational levels of the typical shop floor worker and the high employee turnover rates.

On average these companies have a 10% annual turnover rate. A Best Manufacturing Practices Center of Excellence (1996) survey conducted at Nascote Industries, Inc. identified an employee turnover rate of 1% in this 600 employee, supplier of exterior trim products for the automotive industry from Nashville, Illinois. This was partially accomplished through the strong commitment of management to the quality of its employee's lives and that of the company's products.

The above factors implicitly reduce top management's commitment to encouraging employees to take a more active role in the company. Consequently, productivity is low, shop floor salaries for new employees are close to the minimum salary permitted by law, workers are basically expected to perform specific, physical operational tasks, and training merely focuses on adapting workers to undertaking these tasks when new production processes are introduced. No significant and decisive steps are taken to improve the employees' overall working conditions or in addressing the intellectual needs of the employees through training. As a result, companies are facing increasing difficulties in hiring and maintaining younger workers.

Manufacturing Performance

If the analysis of the external factors is important for determining the competitive positioning of this industry, evaluating the manufacturing performance of the companies is essential for identifying areas of improvement. Contrary to the case of external factors, manufacturing performance is largely dependent on the company's competencies and capabilities and less on elements it may only influence but cannot control. This enhances the value of some of the recommendations made at this level.

Figure 36 (a-e) - Performance Variations for All Components

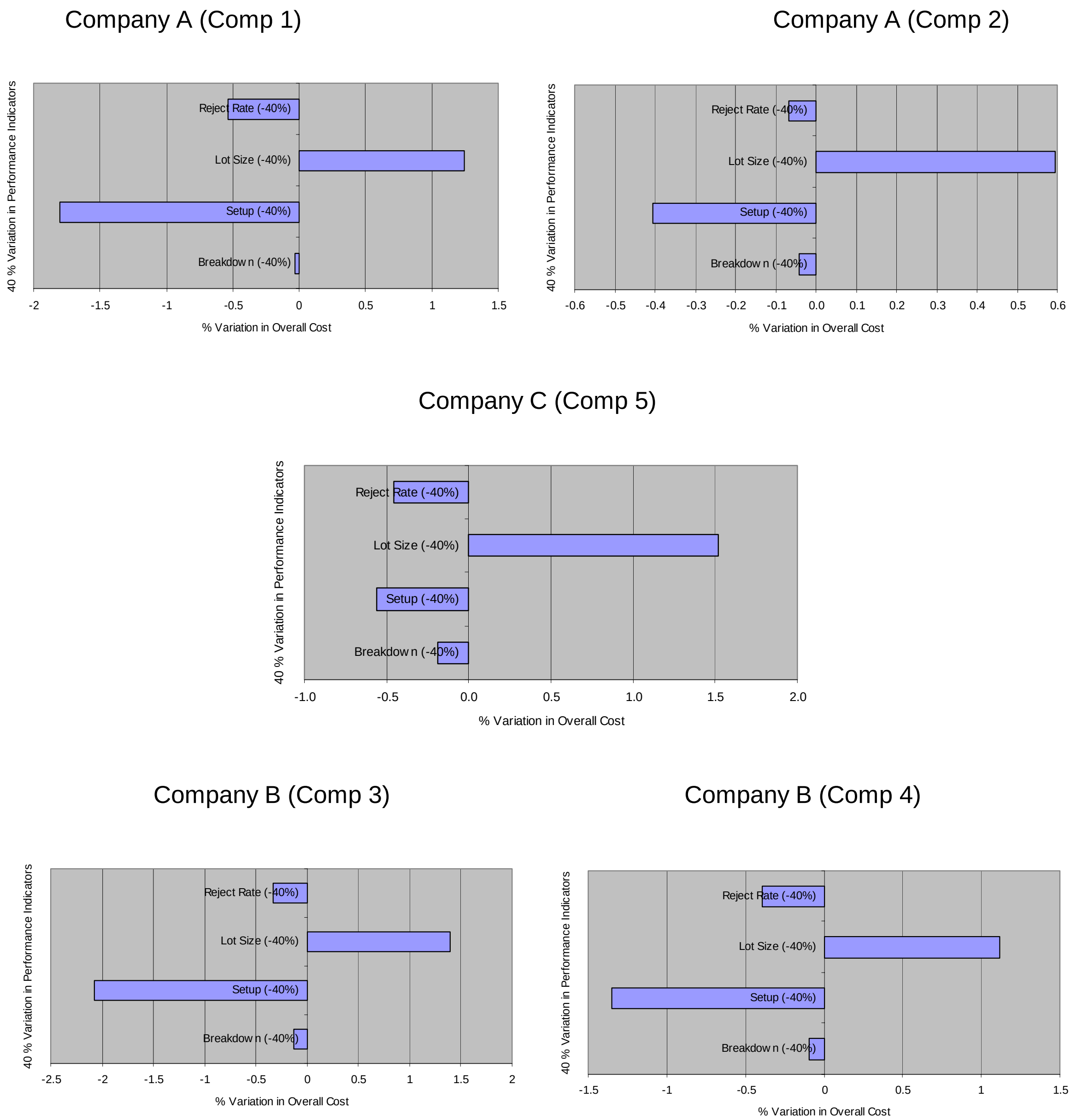


Figure 36 (a-e) points towards significant cost reductions deriving from set-up time optimisations. On the other hand, improving flexibility through lot size reduction may lead to important cost increases. Notwithstanding the added costs resulting from smaller production lot sizes, these costs are partially determined by set-up times and, as such, a reduction in lot sizes is possible as long as progress is made in this area.

Flexibility

Considering that Comp 3 and Comp 5 represent the best and worst case scenarios in terms of the relation "reduction in set-up time / reduction in lot size" respectively (Figure 36), we shall now try to determine an equilibrium position in which, for these two components, the pros and cons are balanced.

Figure 37 - Set-up Time / Lot Size Variations Company C (Comp 5)

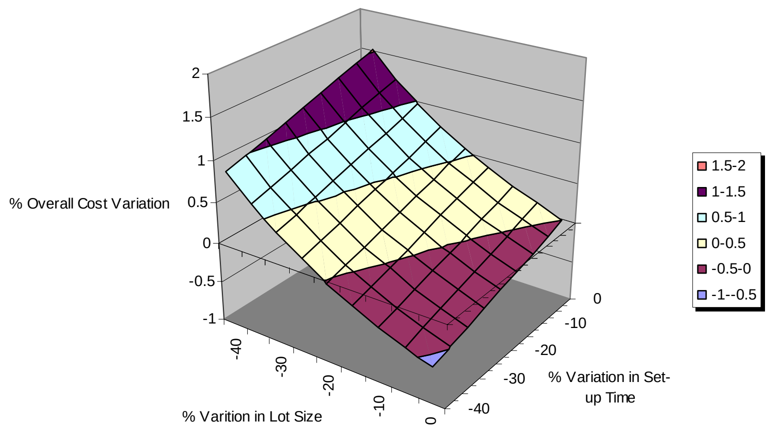
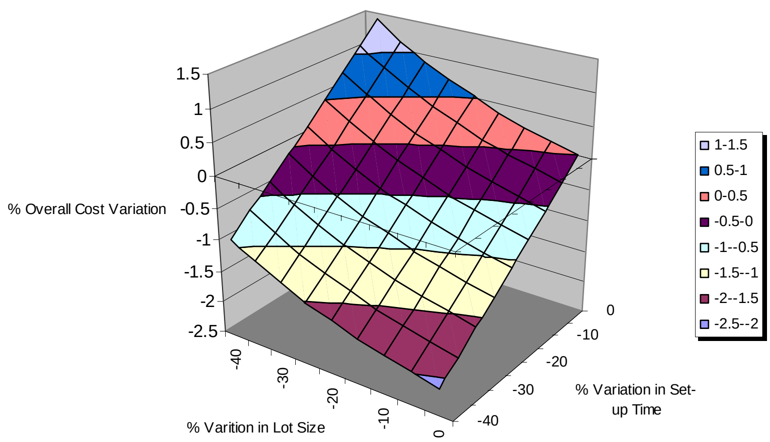


Figure 38 - Set-up Time / Lot Size Variations Company B (Comp 3)



As can be seen in Figure 37 even for the component that shows greater cost increments resulting from reducing lot size, cost reductions are possible for lot size reductions of less than 25% if accompanied by set-up time reductions greater or equal to 40%. For the component that is less sensitive to lot size fluctuations, overall cost reductions are possible even with 40% lot size reductions.

The analysis of set-up times is extremely relevant due to the fact that much is still to be done towards their reduction in most companies. In fact, in the blanking and stamping manufacturing technologies (with 44% of the overall costs excluding raw material), where the costs pertaining to set-up times are considerable due to the loss in utilisation of the expensive equipments and tools that, as we have previously seen, account for a significant part of the costs associated to these technologies (approximately 60% of the costs incurred in these two technologies excluding raw materials), current set-up times for some presses are in the order of 1 to 1½ hours. On the other hand, set-up times are mainly constituted by die change times. As we know, optimisation of procedures and investments in rapid die change equipment can lead to very significant time reductions. As an example we can refer that AutoEuropa in its press shop has die change times of 12 minutes for presses and dies that are substantially larger than the presses used in the production of the components under analysis.

Since rapid die change equipments are relatively expensive, initial efforts must focus on the optimisation of procedures where much can be still be improved. The fact that situations exist during die change operations where workers are confronted with the absence of an indispensable resource and the operation is suspended until the resource is made available, is indicative of the kind of gains that are possible if these operations are adequately planed. Considering that these situations are quite frequent and that they reflect the absence of adequate procedures, investments in expensive die change equipments are presently unwarranted.

Quality

As was mentioned in Chapter 3, manufacturing performance, measured in terms of quality, will be analysed according to the level of breakdowns and defect rates. While both these factors have an influence on costs, they equally reflect the level to which product and manufacturing process designs are mastered. In fact, while adequate product design and development can contribute to reducing the level of breakdowns and defect rates by guaranteeing the product's manufacturability, since most companies are generally not responsible for product development, the following analysis will focus on manufacturing performance.

In order to assess the cost incurred due to non-quality, breakdown times and defect rates pertaining to all technologies are annulled. The difference between the value initially estimated for the component and this cost corresponds to non-quality costs.

Table 20 - Non-Quality Costs

Company A		Company B		Company C
Comp. 1	Comp. 2	Comp. 3	Comp. 4	Comp. 5
1.5%	1.3%	1.2%	1.3%	1.6%

The figures in Table 20 point towards non-quality costs accounting for approximately 1.38% of overall costs. Simultaneously, internal defect rates are still reasonably high. For example, in the blanking and stamping technologies, the average level of defective parts is 500 ppm (parts per million) and 2000 ppm respectively. International best-in-class standards in terms of internal defect rates in the automotive stamped components industry point to substantially lower values.

On the other hand, these companies' defect rate values, measured at OEMs assembly units, are substantially lower. On average, these companies have external defect rates of 450 ppm. Indeed, since these companies compete in one of the world's most demanding markets – the European market – it should be expected that they compete at least according to OEM average global values. This value varies amongst OEMs – Ford suppliers average 650 defective ppm while Toyota and Honda values are between 60 and 90 (Ernst & Young LLP, 1998).

Ultimately, eliminating the differential between internal and external defect rates can only be achieved through significant efforts in inspection that identify and remove the defective parts from the system before they reach the client.

The present situation is a direct result of the past experience of the companies with quality certification: OEMs have, during the last decades, imposed severe restrictions on supplies by companies that do not posses quality certifications according to specific standards, in some cases, defined by the OEMs themselves. This has forced many companies to seek certification so as to fulfil these requirements and less as a means of optimising the use of their resources. Although this perspective towards quality is rapidly changing, improvements take some time because the main issues influencing change are essentially of a cultural nature. Presently, according a taxonomy suggested by Mckinsey and Co. (1994), these companies' philosophy towards quality could be classified as Phase II, but with certain characteristics pertaining to Phases I and III, where:

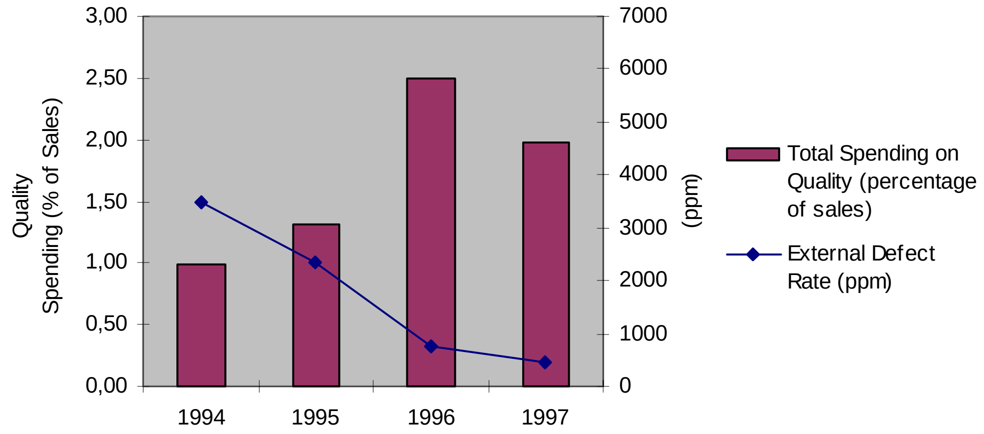
Table 21 - Quality Philosophy according to McKinsey and Co.

Phase	Underlying Philosophy
Phase I	Companies seek quality through inspection. Quality control department is given responsibility for product quality, primarily by discarding defective items at the end of the production process.
Phase II	Firms have a better grasp of how their processes work, and tend to grant responsibility to the production department that employs more advanced tools such as SPC.
Phase III	Companies have completely switched to prevention as opposed to remediation. Advanced tools such as FMEA are employed. All departments work jointly.
Phase IV	Companies strive for perfection in output not only by crossing internal functional boundaries, but reaching out as well to external partners. All internal departments must be served as if they were external customers.

Source: McKinsey & Co.

Best practices in quality spending and external defect rates identified by the McKinsey & Co. study in 1994 pointed towards 0.8% spending in quality as a percentage of sales and 70 ppm external defect rates.

Figure 39 - Evolution in Quality Spending and External Defect Rates

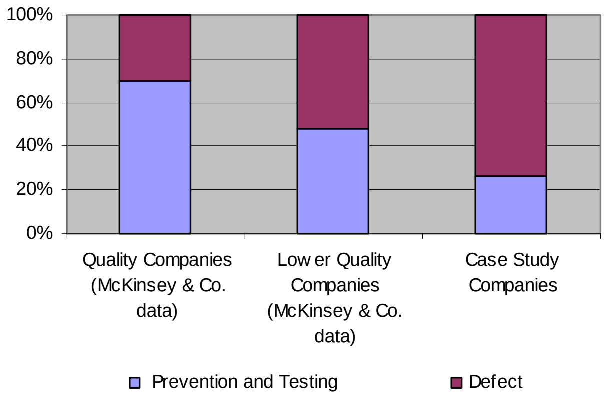


Source: McKinsey & Co.; Case Study Data

By comparing the case study companies' values presented in Figure 39 with the sample average, in 1994, these companies would fall into the Phase III or IV categories (3.6%) in terms of quality spending and in Phase II (887 ppm) in terms of external defect rates. The average quality spending, in 1997 for the three companies, of 1.98% of sales is consistent with the values presented in Table 20 that pointed towards non-quality costs of 1.38% of overall cost. Considering a 7% profit margin for the five components under analysis, non-quality costs can be estimated at 1.48% of the sales price of the components. Since these values do not account for any indirect resources allocated to quality, a difference of 0.5% of the sales price seems to adequately reflect these added costs.

Subdividing quality spending according to the three categories considered by the McKinsey & Co. study, namely, prevention, testing, and defects, the following results were obtained.

Figure 40 – Quality Expenditure Analysis



The results point towards a very significant part of quality spending being relative to defects. On the other hand, the fact that significant levels of non-conformities occur in products that have been in production for a significant number of years puts the emphasis on manufacturing competencies and capabilities, and/or on the degree of effectiveness of the management techniques employed in manufacturing and quality. Together, these values seem to suggest that companies are relying on corrective measures as opposed to investing in prevention actions.

By looking at the evolution in external defect rates presented in Figure 39, the reduced investment in preventive actions, and the differential between internal and external defect rates, it is possible to conclude that the reduction in external defect rates has primarily been based on corrective actions. This strategy has led to an increase in quality expenditure over the period under analysis. Notwithstanding this increase, quality spending remains lower than could be expected. Considering the reduced value added of the products manufactured by these companies, in the short-term, relying on corrective measures may actually be cost effective. This is possible if the investments in prevention clearly outweigh the costs of the corrective measures. When faced with the previously mentioned external pressures, which push towards substantial reductions in external defect rates, this strategy may in fact be adequate.

In the long-term it will have extremely negative consequences because the primary factor contributing to quality expenditure – internal defect – are not significantly impacted.

Besides pointing towards a great uniformity between companies in terms of quality performance and large improvements in external defect rates during the period under analysis, these results equally highlight the fact that large improvements are possible. With a 40% improvement in quality amongst GM's global suppliers over the 1996 – 1997 period, and Ford revoking 61 of its suppliers' Q1 status worldwide (Ernst & Young LLP, 1998), companies that can not reduce the internal defect rates accordingly will eventually loose their remaining competitive advantages (namely price) because the resources involved in manufacturing and scraping, or reworking large quantities of defective parts will eventually become economically unviable.

Flow Time

Flow time analysis will be limited to evaluating actual processing times since no data was available on the time spent by the intermediate products in-between processes. Comparing these firms' performance to data from other companies is equally unviable since flow time is significantly influenced by the component's characteristics. This would only be possible if similar components were manufactured by other companies and access were given to their data.

The following flow times where found:

Table 22 - Flow Times

	N. of Observations	Minimum (s)	Maximum (s)	Average (s)
Blanking	3	2	7.2	5.5
Stamping	13	1.74	60	11.3
Welding	4	5.5	25	12.1
Assembly	3	10	14	12
Painting	4	2098	3358	2414

The results point to significant differences in flow time within the same technology, specially in the case of the stamping and welding technologies. In the case of stamping the difference essentially in the nature of the product, this is, parts that are deep drawn have significantly larger flow times than parts which are not. On the other hand, although recent investments have been made in the acquisition of mechanical presses, slower hydraulic presses are still quite common. These presses are normally used for the lower production volume parts as a means of optimising the use of the existing resources.

In relation to welding, the variation is the result of the number of different welding operations required by the component. Welding and fastening are very similar in terms of flow time due to the fact that flow times are determined, namely by the handling required for placing the part on the fixture. It is therefore important that these fixtures be carefully designed in order to reduce handling time.

The painting technology, where on average, a component partially occupies the line during 40 minutes, has by far the largest flow time. Since a significant part of the painting technology costs pertain to equipment investment, special attention must be given to, on the one hand, quality control before the components are placed on the line, herby avoiding line space utilisation with parts that will ultimately be scraped, and on the other, optimising the hangers on which the parts are hung. The use of common hangers for a wide variety of components must therefore be limited to components with similar sizes and geometry where the cost of developing and producing new hangers is larger than the benefits in terms of line optimisation.

Cross Analysis of Exogenous Factors and Performance

Since changes in external factors and companies' performance do not occur separately, a combined analysis will be made in which it is possible to analyse the level of performance improvement which is necessary to counteract negative changes in the exogenous factors.

The performance measures and exogenous factors considered in the analysis are:

Table 23 - Exogenous Factors and Performance Measures

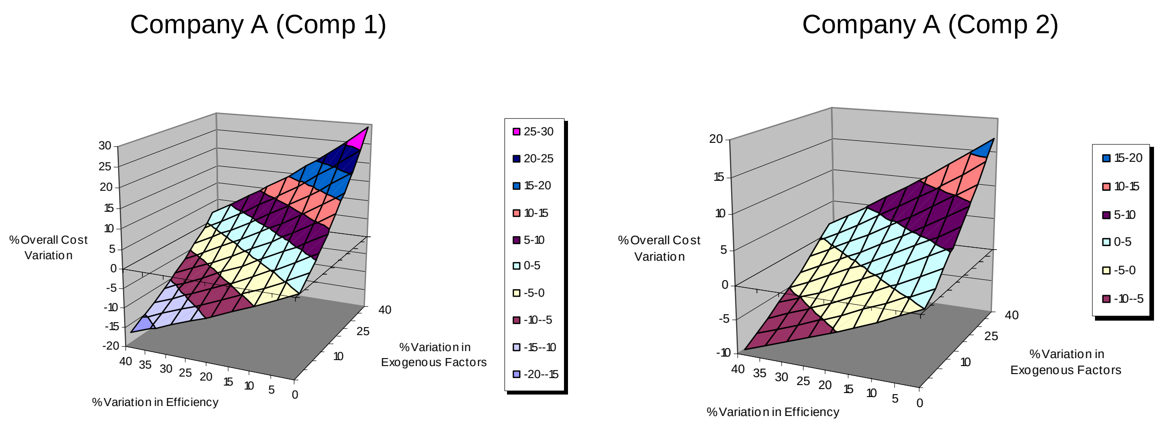
Exogenous Factors	Performance Measures
Working Days per Year	Breakdown Times
Wages	Set-up Times
Energy Costs	Defect Rates
Interest Rate	Line Rates
Cost of Space	

Variations in the cost of raw materials were not considered relevant to the analysis since any change at this level will not impact the competitiveness of these companies alone, but the global industry. This analysis would only be relevant if raw material import tariffs in place in Portugal differed substantially from the EU average, which is not the case. Moreover, it is extremely unlikely that any substantial differences will exist in future.

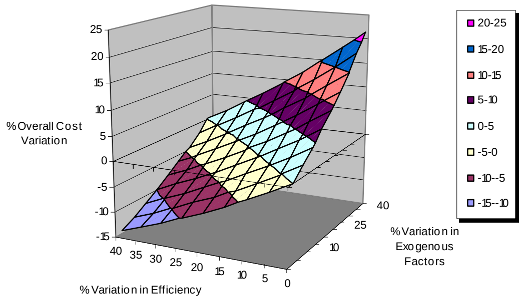
The results presented in Figure 41 were obtained by, on the one hand, simultaneously varying the five external factors according to equal amounts and, on the other, doing exactly the same for the four performance measures. These two variations were undertaken simultaneously and their impact on cost was determined. Variations that do not yield changes in cost (the line that separates the light blue and yellow points of the graph) represent equilibrium points in which improvements in performance annul the negative impact of the variations in the exogenous factors.

The following results were obtained for the five components under analysis:

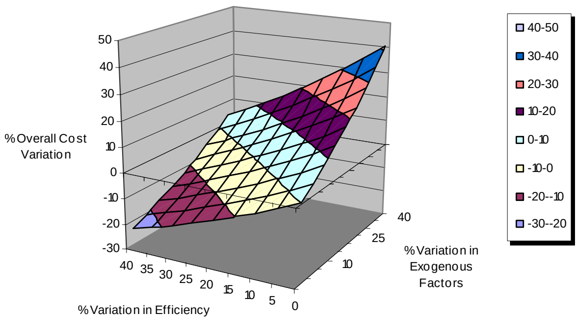
Figure 41 (a-e) - Exogenous Factors vs Manufacturing Performance



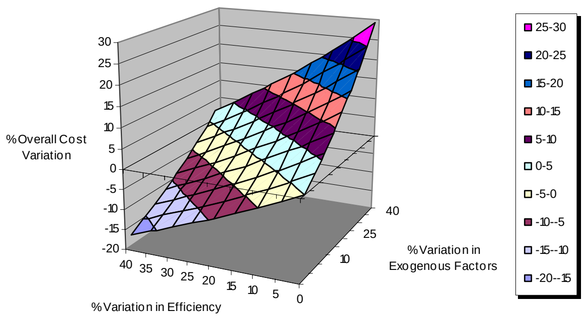
Company C (Comp 5)



Company B (Comp 3)



Company B (Comp 4)



As can be seen from the analysis of these figures, a 20% increase in the cost of the inputs can be compensated by slightly higher percentage gains in performance, hereby maintaining the overall cost at the same level. Simultaneously, when we look at the individual results, a clear trend towards the smaller sized products being able to accommodate larger exogenous factor variations, is present. This is well visible if we look at the two heaviest parts (Company A products) and the lightest part (Comp 3) where similar exogenous factor variations for the first group can only be compensated by higher performance improvements than that of the second.

These results suggest that, if the exogenous factors do in fact evolve in a significantly unfavourable manner, the companies producing the smaller, more complex components will have comparatively less difficulties in minimising the negative impact of this situation. The greater complexity of the components, in practical terms, means that the company's intervention is equally greater. Consequently, performance improvements have a greater impact on cost and the exogenous factors are less influential. Ultimately, this represents a situation in which the company is less vulnerable to variations in its environment.

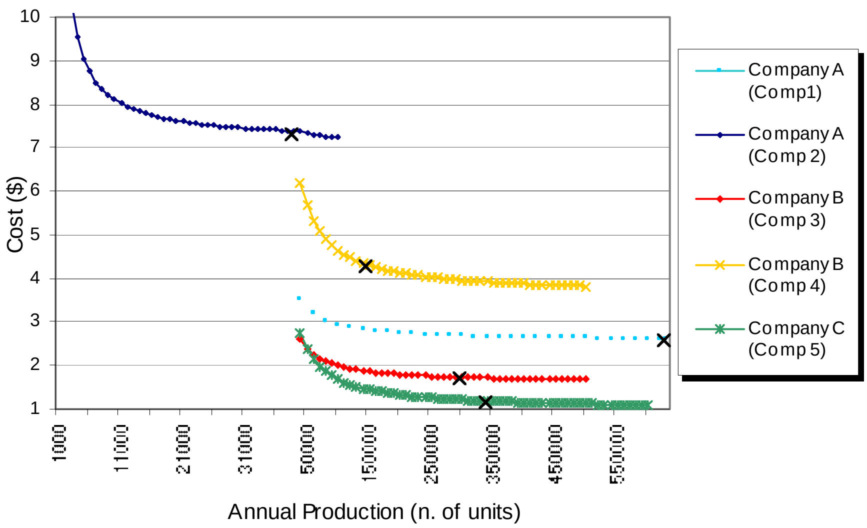
Notwithstanding the fact that this analysis is highly dependant on the nature and number of external and performance factors considered, the main objective in this exercise is to try and estimate the manufacturing performance improvements that are necessary when companies are faced with disadvantageous exogenous factor variations or the need to reduce costs on a yearly basis as a result of OEM pressures (e.g. Ford is demanding price cuts of 5% per year from its suppliers. (Ernst & Young LLP, 1998)).

4.2.3.1.2.2 Scale

Annual Production Levels

All the companies analysed are working according to annual production volumes that are in the region where the correlation between unit costs and production volume is weak (see Figure 42). That is, variations in production volumes around the present levels do not induce significant variations in fixed costs per part produced. An adequate relation between investments and production levels is thus present. The fact that most fixed costs pertain to non-part specific investments (production and automatic feeding systems and consequently space occupied are used to approximately fool capacity throughout the year in the production of the component under analysis, or more frequently, in the production of a wide variety of other products), reduces the variation in cost, due to different production volumes, to the investments made in for instance tools.

Figure 42 - Cost (Annual Production Level)



Capacity Utilisation

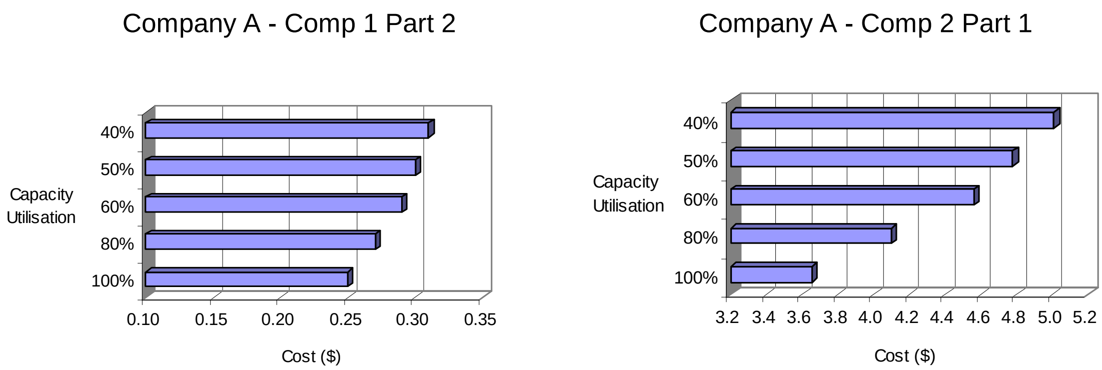
Good manufacturing performance and favourable exogenous factors alone are not sufficient to guarantee manufacturing cost competitiveness. Adequately utilising available capacity is equally essential. The costs incurred due to the lack of capacity utilisation can be summarised as being the loss of revenue resulting from not utilising the available resources to their full potential. In practical terms, this corresponds to supporting all the fixed costs and loosing the company's profit margin, essential to guaranteeing adequate shareholder return and the financial resources required for the undertaking investments.

Due to the lack of data pertaining to the individual technologies' level of utilisation over an extended period, the simulations which were undertaken considered that the production technologies' available capacity is utilised to its full potential. While for some technologies such as painting, this assumption corresponds to reality, in the case of e.g. stamping it may be far from representing the present situation. Namely, when the investments in production equipment are less significant (e.g. the cost of individual presses vs. the cost of transfer or progressive die processes) the utilisation of those equipments tends to be lower.

In order to better understand the costs incurred due to not utilising available capacity to its full extent, an analysis shall be carried out for the two components with the smallest and largest production volumes, Comp 2 and Comp 1 respectively.

Since utilisation rates are not constant among technologies or even within the same technologies due to the different production flow times of distinct parts, the analysis will be based on the stamping costs of two parts. As previously mentioned, the calculation of production costs was based on the assumption that all available capacity is being utilised. As such, the base price corresponds to a 100% utilisation in the following figures.

Figure 43 (a-b) - Capacity Utilisation



The results indicate that maintaining reasonable levels of capacity utilisation is an important factor for keeping down costs. In fact, for Comp 2 Part 1, a 50% reduction in capacity utilisation could lead to a cost increase of 30%. Considering that the production of Comp 2 Part 1 only fills 28% of the stamping equipment's total capacity, if the equipment were solely used in the production of this part, significant cost penalties would result. As for Comp 2 Part 1, the cost difference between 100% and 50% utilisation is smaller, and equal to 20%.

On the other hand, optimising capacity utilisation is largely dependant on factors such as production planning capabilities, increasing the number of equipment options available for producing a specific part through process flexibility (e.g. standardising tool fixtures so that a part can be produced in a variety of different presses), balancing manufacturing technologies with product portfolio, etc.

While some firms are currently taking some steps in this direction, the previously mentioned weaknesses in terms of operational and strategic planning, limit the companies' capability to significantly improve the level of utilisation of available capacity.

4.2.4 Overall Competitiveness Analysis

The analysis presented in the previous section points towards different levels of competitiveness of the three companies under analysis. In the two most aggregated measures of competitiveness used in this dissertation, distinct results were reached. In fact, if in terms of profitability these companies have average or above average results, in relation to the evolution in market share they have a ratter sluggish performance.

Instead of analysing the absolute value of market share the analysis of market performance was based on the evolution of sales revenue in comparison to other automotive suppliers. According to the results, growth in revenue in the sample of foreign suppliers clearly supplanted that of the Portuguese companies, notwithstanding the fact that two of the three companies increased their sales revenue over the period under analysis. In a context of generalised growth in the automotive components industry resulting from increasing levels of outsourcing by OEMs, this evolution is clearly indicative of a loss of competitiveness.

On the other hand, the competitive positioning of these companies is essentially based on price competitiveness since quality, delivery time and reliability are unilaterally defined by OEMs and cannot be seen as variables that differentiate these companies from their competitors, but instead as a prerequisite for doing business in the original equipment market. In this context, a company is competitive in a specific market if it can supply that market with price competitive component.

By varying the exogenous factors according to the reality of three European countries, production costs in Portugal were compared to those that would be incurred in if the exact same manufacturing processes were transplanted to these countries. Whereas in the case of the two Central European analysed, Portugal has a clear cost advantage, in relation to the East European nation analysed, there is a slight disadvantage. The development of the automotive components industry in these countries may in fact posse a threat to the national companies if they do not evolve to higher added value products and services. This cost disadvantage may in fact be responsible for the sluggish growth in sales revenue during periods of strong widespread growth in this industry.

Despite the contribution of the cost of inputs towards determining the overall cost of a product or service, the company's performance in transforming inputs into outputs is perhaps even more important. In this context, labour productivity in the three companies was compared to that of other automotive suppliers. The comparative analysis of labour productivity (measured in terms of turnover per employee) revealed significantly lower labour productivity levels in the Portuguese companies. These differences can in part be attributed to the favourable costs of labour and the unfavourable cost of capital in Portugal when compared to other countries. This leads to the utilisation of more labour-intensive solutions where employees often undertake tasks that in other countries are executed by machines. If the lower labour productivity levels of the three companies in relation to foreign competitors may not necessarily represent a disadvantage in terms of the effectiveness and efficiency of the employees' work, the limited growth rate in labour productivity in these companies must be interpreted as a clear loss of competitiveness. In a period during which substantial investments are starting to be made in more automated equipment, stagnating labour productivity levels may actually reflect a significant loss in overall productivity.

Although the present dissertation did not prove or even seek to prove, that these figures are partially the result of the low level of education of the employees belonging to all hierarchy layers, various international studies have found that a strong correlation between educational level and productivity does in fact exist. Considering what has been presented throughout this thesis in relation to the level of competencies existing within the three firms, there is a strong possibility that the educational level of the employees largely determines the internal performance of these companies.

5. CONCLUSIONS AND RECOMMENDATIONS

The exponential growth, which has characterised the Portuguese automotive components industry during the last decades, is presently giving place to significantly lower growth rates and increasing difficulties for some of the companies in the more traditional areas of activity such as stamping. While the individual company's competitiveness is largely determined by its own actions, past experience has shown that the lack of awareness of the companies to this industry's very specific characteristics and their evolution, together with the inability to define coherent long term strategies, has led to increasing difficulties for many companies. This thesis thus sought to contribute with that which is often lacking in the companies – a strategic perspective to their activities.

In addition, the importance this sector of activity has assumed in the Portuguese economy and the recognition by the Government of its strategic importance in terms of structuring effects it has on the industry as a whole makes any contribution towards its development extremely relevant.

The methodology used was partially based on the assumption that understanding the future competitive positioning of this sector in Portugal can only be accomplished if one understands the past and present situation of this industry.

According to the case study analysis model, five distinct levels of competitiveness where defined, namely: (i) profitability, (ii) market share, (iii) product attractiveness, (iv) factors defining product attributes and (v) management and scale efficiencies. The presentation of this dissertation's conclusions and recommendations will thus be made in accordance to these five levels. Lastly a set of recommendations will be made in relation to product strategies and workforce training.

Profitability

While profitability is essential to the firm in the short and medium term, the comparative analysis of a company's profitability with the industry average may shed some light on the future competitiveness of the firm.

According to the four profitability indicators utilised in the analysis, for the two Portuguese automotive components case study companies in which financial data was made available, profitable levels supplant the average values of a sample of foreign international first tier suppliers. Moreover, the results point towards profitability levels that may in fact be quite higher than the industry average.

Market Share

Despite the substantial growth that has characterised the automotive components industry at an international level, this growth seems to have had a smaller impact on these three companies. Notwithstanding the reasonable growth in turnover of two of the case study companies, this growth is substantially weaker than that of other companies in the same industry. This can be interpreted as a loss of competitiveness in relation to their competitors, which have capitalise on some of the opportunities which have resulted from the restructuring of the automotive industry and the increasing level of outsourcing by OEMs.

A possible explanation for the slower growth rate of the Portuguese case study companies may lie in the type of growth strategies used. While Portuguese companies have based their growth on developing internal capabilities, their foreign competitors have complemented the growth achieved in this manner with mergers and acquisitions. In an environment characterised by OEMs demanding constant reduction in unit costs, systems design and production capabilities, and global reach, internal growth is often an insufficient strategy for responding to these solicitations.

The fact that three companies exhibit profitability ratios above industry averages but simultaneously grow at a slower pace seems to confirm the limitations of the current growth strategies.

Considering the specificities of the sector at a national level, when faced with the substantial investments required and the need to minimise the risk involved in entering these activities, co-operation is perhaps the best-suited strategy for developing capabilities in previously unexploited areas of activity. Since product design and development, and the assembly of more complex products (modules and systems) are two probable areas in which companies will be seeking to invest in the medium-term, they should consider doing so in co-operation.

Product Attractiveness

The nature of the products manufactured by these companies and the limited product development capabilities clearly place these companies in the commodities market where price is the single most important factor determining the company's competitiveness. This does not mean that price is the only factor clients consider in their purchasing decisions. What it in fact means is that other product attributes such as quality, and delivery time and reliability are unilaterally defined by the clients. Suppliers that cannot guarantee these product attributes are not even considered in OEMs purchasing decision process.

Factors Defining Product Attributes

Cost of Inputs

The companies analysed have taken good advantage of the Portuguese exogenous factor conditions. Within this context, labour costs remain well under the EU average, which unquestionably constitutes a competitive advantage in relation to other European competitors. This is an important advantage if one considers that labour costs (direct and indirect labour costs) still account for approximately 19% of the overall costs.

But, if in comparison to countries such as Germany and France the three companies have a clear cost advantage deriving form the set of exogenous factors considered in this comparative analysis, in relation to e.g. the Czech Republic, a slight disadvantage may exist. In fact, if the exact same firms were transplanted to this country, the total cost of manufacturing the five components under analysis would be lower than in Portugal. Moreover, the greater geographical proximity of some East European countries to the main vehicle assembly markets represents an added disadvantage for the Portuguese companies.

While in the short to medium term the competition from companies belonging to these countries will continue to be based mainly on price, the Portuguese companies must rapidly evolve to the design, development and production of higher added value products. In the past, similar strategies have been employed, when, besides supplying vehicle components, stamping companies developed stronger relations with their clients by offering them competencies and capabilities in the design and production of tools.

If this is not accomplished companies from Eastern Europe will eventually evolve to performance standards in manufacturing low value added products that, coupled with more favourable exogenous factors, will threaten the national firms' positioning as a least cost option.

During the period of transition, the trend towards the reduction in interest rates as the Portuguese economy is increasingly integrated within the EU opens up good prospects for investment in more capital-intensive processes.

The present levels of automation are favourable to an overall increase in the level of automation as long as this change is accompanied by a reduction in labour costs, or/and productivity increase, or a reduction in interest rates. Nevertheless, if interest rates where to remain above EU average and salaries short of that of competing European countries, the Portuguese competitive positioning must necessarily continue to be based on comparatively less automated processes.

Productivity

The analysed companies' labour productivity (measured in terms of turnover per employee) is significantly lower than that of other foreign firms in similar areas of activity. While the results are partially the result of a greater use of labour by the Portuguese companies, they may equally reflect lower levels of efficiency and efficacy in the work undertaken by employees.

Considering that various studies have positively correlated productivity and wages, it is by no means surprising to find substantial differences in productivity if one considers that wages in Portugal are significantly lower than in most EU countries. In fact, labour productivity in the three companies remained relatively unchanged during the four-year period that preceded this analysis, period during which, on average, substantial growth has occurred in terms of turnover and the size of the workforce.

In an industry where the annual price reductions demanded by OEMs impose constant productivity gains, this situation may lead to a loss in competitiveness in the short term. Considering that the difference in the cost of labour between Portugal and other EU countries will probably continue to decrease, and the significant use of labour in the companies' operations, substantial gains in labour productivity must continue to be sought if companies are to remain price competitive.

The productivity gap is widely recognised by company CEOs, which consider the level of qualification of the human resources as the main factor impairing greater convergence to international standards. Various international studies have pointed towards the deficient literacy levels in Portugal resulting from low level of education of the population as a whole, and the workforce in particular. Considering that a person's literacy level directly influences his or her ability to understand and employ printed information in daily activities at work and to develop one's knowledge and potential, the impact on the individual's professional performance of a low literary level is clearly understood.

Moreover, the same studies identified significant deficiencies in all professional categories, including managers. As such, the low qualification of the human resources in the lower hierarchy levels must not be seen as the sole cause of some of the deficiencies occurring in these enterprises, but rather as a piece of a more complex puzzle in which the skills of the companies' CEOs and managers play an equally important role.

Considering that deficient literacy levels are highly limiting of a person's professional activity because they reflect difficulties in undertaking basic activities, companies must give added attention to leveraging the general skills of the workforce before investments are made in more specific training. In situations in which the general qualifications of the employees are weak, preference must be given to training that improves the general skills of the workforce and less to supporting workplace change. If training continues to be directed at responding to needs imposed by changes in the workplace, literacy levels will remain practically unchanged and the impact on labour productivity will most probably continue to be reduced.

In fact, since significant efforts have been made in the acquisition of physical assets during the last years and these investments have not been accompanied by equal gains in labour productivity, the underlying issues may in fact be the qualification level of the workforce and a possible misinterpretation of its impact on the success of the investments made. In the past, investments have sought to avoid the move to technologies that demand higher skill levels. Studies have shown that the substitution of unskilled by skilled labour is only cost-effective if accompanied by technological change making skilled labour relatively more productive. As such, besides the low level of qualification of the human resources, the sluggish growth in labour productivity during periods of strong investment by the firms may be the result of investments in physical assets that are inconsistent with the efforts made in training because they do not lead to the increase in demand for skilled labour.

Management and Scale Efficiencies

Management Efficiencies

Flexibility

One of the traditional explanations for the relative success of Portuguese companies is their small size and high level of flexibility. And in fact, when one looks at the companies' product portfolio we can identify a diversity that suggests such flexibility must in fact exist. But when examining the aspects which normally define the level of flexibility of a company's manufacturing process these are generally underdeveloped. Rapid die change techniques are a good example of tools that can yield substantial set-up time reductions, which are only now beginning to make their way into these enterprises. Notwithstanding the fact that the benefits of added flexibility are by no means limited to cost reductions, case study results have shown that important reductions in costs are possible (which in the case of one component reached 2% with a 40% reduction in set-up) if some set-up time optimisation processes are implemented. As previously stated, it is not mandatory that expensive die change equipments be bought and implemented since significant improvements can be achieved through simple process optimisations.

Presently, the high levels of flexibility seem to be maintained somewhat artificially with negative results in terms of cost. As such, the flexibility which transpires to the exterior, frequently does not have a corresponding level of internal flexibility. What in fact happens is that significant final product stocks are maintained so as to quickly respond to customer solicitations.

The importance raw material costs have on overall cost, the fact that costs with materials are incurred as soon as they are bought form the supplier, and the handling requirements of some of the more complex components, should lead companies to consider implementing work cells. This could lead to greater levels of efficiency and reduced raw material, and intermediate and final product stocks. Moreover, cellular manufacturing systems have gained acceptance in recent years (Swamidass, 1998) in both large and small plants because they are more efficient than job shops and more flexible than flow shops.

Quality

A new perspective towards quality certification is currently starting to appear in the Portuguese automotive stamping companies, as they move away from certification as a means of gaining access to OEMs and begin looking at certification as a way of leveraging technological competencies, which in turn, will ultimately lead to fewer breakdowns and reduced defect rates. Notwithstanding this new posture, manufacturing performance, measured in terms of quality levels, can be greatly improved – internal defect rates in blanking and stamping are significantly higher than could be expected from certified companies. The significant level of non-conformities for products which have been in production for a significant number of years seem to suggest that the main issues are in fact in manufacturing and not in the product design and development phases. At the present levels of non-conformities one could equally expect to find situations in which the same problems are repeatedly occurring. This suggests that adequate measures are not being taken and methodologies are not being implemented to minimise the reoccurrence of the same problem.

Once again, the explanation for this situation seems to lie in the shortage of qualified human resources capable of identifying the source of the problems, and defining and implementing adequate solutions. As a result, companies are "forced" to concentrate on the quality of the outputs, which when conjugated with the use of higher levels of quality control on final and intermediate products guarantee that the external quality levels are kept at reasonable levels. Maintaining external defect rates below contracted levels is of the utmost importance since OEMs control these levels tightly and compensation for breaching agreements is calculated according to the level of damages incurred by OEMs.

Since the current situation is, in the medium and long term, incompatible with the continuous pressure for price reduction imposed by OEMs, the unavoidable solution must consist in the decisive investment in training. Studies have shown that the use of quality circles can generate the high, low risk return on investment which best seems to fit the present situation of the Portuguese stamping industry – authors, such as, Ingle (1983), claim that investing in quality circles yield savings to cost ratio in the order of 5:1.

Flow Time

The results point to significant differences in flow time within the same technology, specially in the case of the stamping and welding technologies. In the case of stamping the difference essentially in the nature of the product, this is, parts that are deep drawn have significantly larger flow times than parts which are not. On the other hand, although recent investments have been made in the acquisition of mechanical presses, slower hydraulic presses are still quite common. These presses are normally used for the lower production volume parts as a means of optimising the use of the existing resources. The financial benefits arising from this solution are questionable.

Flow times in welding and fastening are determined, namely by the handling required for placing the part on the fixture. It is therefore important that these fixtures be carefully designed in order to reduce handling time.

In the painting technology, where on average, a component partially occupies the line during 40 minutes and a significant part of the painting technology costs pertain to equipment investment, special attention must be given to, on the one hand, quality control before the components are placed on the line, herby avoiding line space utilisation with parts that will ultimately be scraped, and on the other, optimising the hangers on which the parts are hung. The use of common hangers for a wide variety of components must therefore be limited to components with similar sizes and geometry where the cost of developing and producing new hangers is exceeds the benefits in terms of line optimisation.

Scale Efficiency

A company's competitiveness in manufacturing requires, on the one hand, good manufacturing performance and favourable exogenous factors, and on the other, adequate scale and capacity utilisation.

The companies analysed are working according to annual production volumes that are in the region where the correlation between unit costs and production volume is weak. That is, variations in production volumes around the present levels do not induce significant variations in fixed costs per part produced. An adequate relation between investments and production levels is thus present.

As to capacity utilisation, while for some technologies, e.g. painting, capacity utilisation is high, in the case of the stamping technologies it may be far from the desired level.

The results obtained in the empirical part of this dissertation indicate that maintaining reasonable levels of capacity utilisation is an important factor for keeping down costs. For one of the components, a 50% reduction in capacity utilisation could lead to a cost increase of 30%. Considering that the same component only occupies 28% of the stamping equipment's capacity, if the equipment were solely used in the production of this part, significant cost penalties would result.

On the other hand, optimising capacity utilisation is largely dependant on factors such as production planning capabilities, increasing the number of equipment options available for producing a specific part through process flexibility and balancing manufacturing technologies with the company's product portfolio.

While some firms are currently taking some steps towards increasing the level of competencies at these levels, the previously mentioned weaknesses in terms of operational and strategic planning, continue to limit the companies' capability to significantly improve capacity utilisation.

Product Strategies

Similar cost structures were identified for components manufactured in the same company. This may be the result of a certain specialisation, in each company, on products that share important characteristics and which lead to similar utilisations of processes and resources. Any product specialisation must be based on a deliberate action by the company to concentrate its efforts on products that can be efficiently manufactured using the company's available competencies and capabilities. Assuming that products have been correctly chosen, important dividends can achieved from product specialisation. Although this dissertation did not establish or seek to establish a relation between adequate product choice and good quality performance, and good quality performance with profitability, various studies have suggested that such a relation does in fact exists.

Simultaneously, if the exogenous factors evolve in a significantly unfavourable manner, the companies producing the smaller, more complex components will have comparatively less difficulties in minimising the negative impact of this situation. The greater complexity of the components results in the company's intervention being equally greater. Consequently, performance improvements have a greater impact on cost and the exogenous factors are less influential. Ultimately, this represents a situation in which the company is less vulnerable to variations in its environment.

Human Resources Training

Lastly, a few comments on what may be the main factor contributing to the poor competitiveness of these companies in certain areas – the educational level of employers and employees and the efforts undertaken by management to minimise its negative impact on the companies' performance.

The potential for improvement in human resource management in the companies is enormous. The extremely low level of commitment between employees and the companies, and visa versa, constitutes an almost unsurpassable barrier in the relationship between employees and employers (or top management) and the sharing of common goals. Possible reasons for the lack of mutual commitment have been identified, but far more important than the identification of the problems, it is necessary to find feasible solutions in view of the specific characteristics of the companies, the employees and of top management.

This must preferably be done by taking advantage of the strong points of the present organisational structure and human resource management techniques. Firstly, the flattened hierarchy structure of these companies must be exploited in order to further approximate employees and top management. This must lead to a greater mutual understanding of employees' personal goals and collective objectives of the company.

Secondly, various studies have pointed towards the direct relation between salaries and productivity, and productivity and educational levels. By investing in training, top management will naturally expect to leverage productivity levels and reduce employee turnover rates that are highly prejudicial to the companies. This must lead to a firm commitment by top management to sharing eventual benefits, resulting form added productivity, with the employees since current shop floor salaries are incompatible with maintaining a stable and motivated workforce.

Since the level of qualification of the workforce is widely recognised has having a substantial negative impact on the overall performance of the companies, present training schemes must be rethought. Decisive steps must be taken so as to include training in more wide-ranging career development programmes, designed to benefit both the business objectives of the companies and the personal growth of the individual employee. This implies tailoring training to the individual needs of the employee, hereby limiting the application of collective training to specific horizontal areas where common needs or weaknesses are identified.

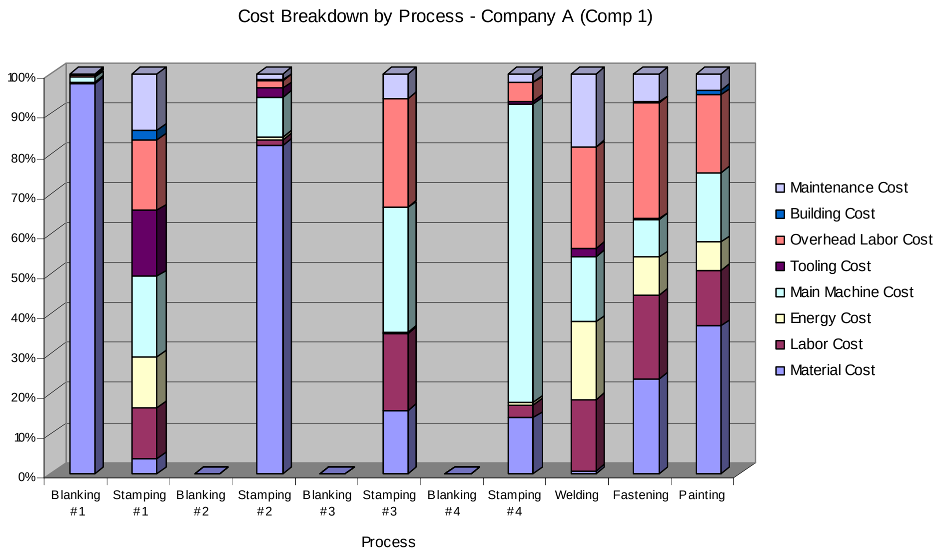
Various research projects have associated high levels of training and low turnover of employees. Companies that invest in training and relate training to promotions and higher wages have lower turnover rates. Lower turnover rates, in turn, constitute an incentive for the employer to continue the investment in training and in the internal promotion of individuals.

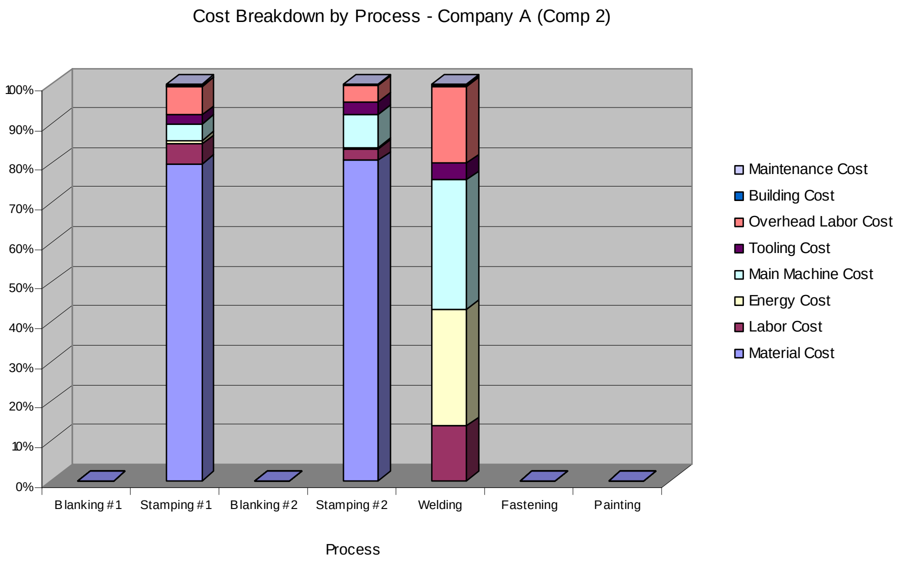
Although the weaknesses in the formal educational of the human resources is a national issue and, as such, not restricted to these companies or the automotive components industry, this must not impede management from continuing to invest in the training of the workforce and in the bettering of the overall conditions offered by the companies to their employees. This calls for a rethinking, by management, of the role of the employees in the companies, transforming what today is a relation between two entities with substantially different objectives into a partnership.

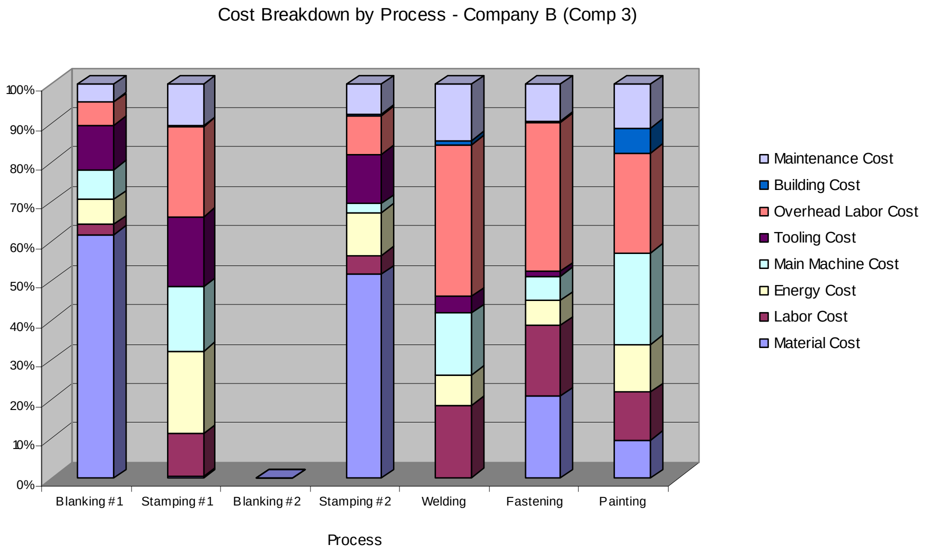
The fact that this step has not been taken may in fact constitute the main obstacle in the transition by these companies from a fragile least cost option, based on the exploitation of advantages in the cost of some inputs, to a new position in which the companies' differentiating factors are less vulnerable to the entry of new competitors from countries with even greater cost advantages.

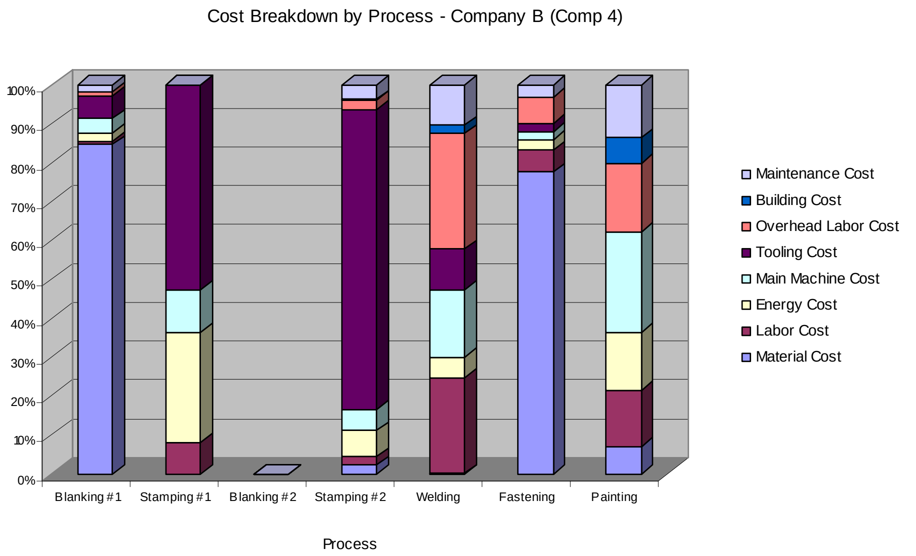
6. APPENDIX

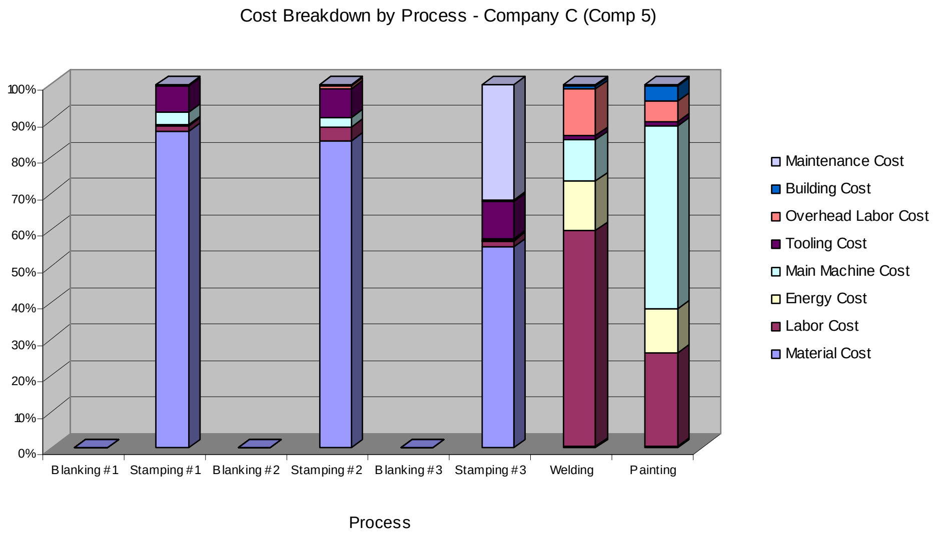
Cost Breakdown by Process






Cost Breakdown by Process - Company B (Comp 3)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Blanking #1
Stamping #1
Blanking #2
Stamping #2
Welding
Fastening
Painting
Process
Maintenance Cost
Building Cost
Overhead Labor Cost
Tooling Cost
Main Machine Cost
Energy Cost
Labor Cost
Material Cost


Cost Breakdown by Process - Company B (Comp 4)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Blanking #1
Stamping #1
Blanking #2
Stamping #2
Welding
Fastening
Painting
Process
Maintenance Cost
Building Cost
Overhead Labor Cost
Tooling Cost
Main Machine Cost
Energy Cost
Labor Cost
Material Cost


Cost Breakdown by Process - Company C (Comp 5)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Blanking #1
Stamping #1
Blanking #2
Stamping #2
Blanking #3
Stamping #3
Welding
Painting
Process
Maintenance Cost
Building Cost
Overhead Labor Cost
Tooling Cost
Main Machine Cost
Energy Cost
Labor Cost
Material Cost

Integrated Blanking, Stamping, Assembly & Painting Questionnaire

This questionnaire is designed to collect data regarding the economics of an integrated operation. This questionnaire consists of three main parts: stamping, assembly, and painting. Please fill this out to the best of your ability and indicate all estimates.

GENERAL QUESTIONS:
These are questions for the final assembled product.

Annual Production Volume		parts/yr
Working Days per Year		days
Average Operation Downtimes:		
Planned, workers unpaid		hr/day
Planned, workers paid		hr/day
Wage		$/hr
Energy Unit Cost		$/kWhr
Product Life		yrs

OVERHEAD QUESTIONS:

These are plant-wide questions that pertain to the total numbers of direct, indirect, engineering and salaried managers. Please indicate the annual cost of these categories of workers. Estimate to the best of your ability.

	Total Number of workers	Total Annual Cost of Workers
Direct workers		$ / yr
Indirect workers		$ / yr
Engineering workers		$ / yr
Management/salaried		$ / yr

TIME:
The time allocated on a line towards making a particular part or assembly is important for us. Please indicate the blanking and stamping divisions of time of a line to the best of your ability. The assembly and painting time allocation tables are later. These times should NOT represent a particular day, but an average over a week or month during which the parts were made. If precise times are not known then please estimate them to the best of your ability.

MAINTENANCE:

There are two main sources of maintenance that we are accounting for: the total annual expense directly associated with the machinery, dies, etc; and the total annual expense for janitorial cleaning, upkeep, etc for the building.

BLANKING AND STAMPING PART 1:

Operating Shifts ____hr.					**Non-operating Shifts** ____hr.
	Parts Production	Breaks and Lunch	Set-up Time	Breakdowns	Planned Idle (lack of capacity & planned maintenance)
BLANKING	hr.	hr.	hr.	hr.	hr.
STAMPING	hr.	hr.	hr.	hr.	hr.

24 hours

BLANKING AND STAMPING PART 2:

Operating Shifts ____hr.					**Non-operating Shifts** ____hr.
	Parts Production	Breaks and Lunch	Set-up Time	Breakdowns	Planned Idle (lack of capacity & planned maintenance)
BLANKING	hr.	hr.	hr.	hr.	hr.
STAMPING	hr.	hr.	hr.	hr.	hr.

24 hours

BLANKING AND STAMPING PART 3:

Operating Shifts ____hr.					**Non-operating Shifts** ____hr.
	Parts Production	Breaks and Lunch	Set-up Time	Breakdowns	Planned Idle (lack of capacity & planned maintenance)
BLANKING	hr.	hr.	hr.	hr.	hr.
STAMPING	hr.	hr.	hr.	hr.	hr.

24 hours

BLANKING PART DESCRIPTION

	PART #1	PART #2	PART #3
Part Weight	kg	kg	kg
Unit Material Cost	$ / kg	$ / kg	$ / kg
Maximum Part Length	mm	mm	mm
Maximum Part Width	mm	mm	mm
Blank Width/Coil Width	mm	mm	mm
Blank Length/Coil Progression	mm	mm	mm
Blank Thickness/Coil thickness	mm	mm	mm
Blank Thickness/Coil thickness	mm	mm	mm
Blanking Material Loss Percent	%	%	%

BLANKING OPERATIONS

	PART #1	PART #2	PART #3
Running Rate	parts/hr.	parts/hr.	parts/hr.
Average Power Requirement	kW	kW	kW
Average Blanking Die Change Time	min.	min.	min.
Blanking Reject Rate	parts/lot	parts/lot	parts/lot
Average Blanking Lot Size	parts/lot	parts/lot	parts/lot

BLANKING EQUIPMENT INFORMATION

	PART #1	PART #2	PART #3
Blanking Line Bed Width (mm)	mm	mm	mm
Blanking Line Bed Length (mm)	mm	mm	mm
Blanking Press Tonnage	tons	tons	tons
Blanking Press Cost	$	$	$
Blanking Die Cost	$	$	$
Blanking Line Space Requirement	m^2	m^2	m^2
Workers per Blanking Line			

BLANKING MAINTENANCE

	PART #1	PART #2	PART #3
Total Annual expense for line	$ /yr	$ /yr	$ /yr
Total Annual building expense	$ /yr	$ /yr	$ /yr

STAMPING OPERATIONS

	PART #1	PART #2	PART #3
Running Rate	parts/hr.	parts/hr.	parts/hr.
Total Line Power Requirement	kW	kW	kW
Average Stamping Die Change Time	min.	min.	min.
Stamping Reject Rate	parts/lot	parts/lot	parts/lot
Average Stamping Lot Size	parts/lot	parts/lot	parts/lot

STAMPING MAINTENANCE

Total Annual expense for line	$ /yr	$ /yr	$ /yr
Total Annual building expense	$ /yr	$ /yr	$ /yr

<u>IMPORTANT:</u>

There are two types of stamping equipment charts. The first one is for transfer or progressive die equipment. All three parts fit onto one chart directly below. The next page concerns tandem die presses. There is one chart for each part. Please use the chart for each part to describe the press line in detail.

TRANSFER OR PROGRESSIVE DIE EQUIPMENT

	PART #1	PART #2	PART #3
Tonnage	tons	tons	tons
Bed Size	mm x mm	mm x mm	mm x mm
Age	yrs	yrs	yrs
Number of Hits	hits	hits	hits
Decoiler (Yes/No)	yes / no	yes / no	yes / no
Average Stamping Tool Set Cost	$	$	$
Total Cost of Line	$	$	$
Press Line Space Requirement	m^2	m^2	m^2

TANDEM PRESS EQUIPMENT FOR PART #1:

Press #	**1**	**2**	**3**	**4**	**5**
Double Action Tonnage Single Action Tonnage	tons tons	tons tons	tons tons	tons tons	tons tons
Bed Size Width	mm	mm	mm	mm	mm
Bed Size Length	mm	mm	mm	mm	mm
Age	yrs	yrs	yrs	yrs	yrs
Number of Hits					
Automation Level					
Average Stamping Tool Set Cost	$	$	$	$	$
Total Cost of Line	$	$	$	$	$
Press Line Space Requirement	m^2	m^2	m^2	m^2	m^2

TANDEM PRESS EQUIPMENT FOR PART #2:

Press #	**1**	**2**	**3**	**4**	**5**
Double Action Tonnage Single Action Tonnage	tons tons	tons tons	tons tons	tons tons	tons tons
Bed Size Width	mm	mm	mm	mm	mm
Bed Size Length	mm	mm	mm	mm	mm
Age	yrs	yrs	yrs	yrs	yrs
Number of Hits					
Automation Level					
Average Stamping Tool Set Cost	$	$	$	$	$
Total Cost of Line	$	$	$	$	$
Press Line Space Requirement	m^2	m^2	m^2	m^2	m^2

TANDEM PRESS EQUIPMENT FOR PART #3:

Press #	**1**	**2**	**3**	**4**	**5**
Double Action Tonnage Single Action Tonnage	tons tons	tons tons	tons tons	tons tons	tons tons
Bed Size Width	mm	mm	mm	mm	mm
Bed Size Length	mm	mm	mm	mm	mm
Age	yrs	yrs	yrs	yrs	yrs
Number of Hits					
Automation Level					
Average Stamping Tool Set Cost	$	$	$	$	$
Total Cost of Line	$	$	$	$	$
Press Line Space Requirement	m^2	m^2	m^2	m^2	m^2

ASSEMBLY:

Operating Shifts ____hr.					**Non-operating Shifts** ____hr.
	Parts Production	Breaks and Lunch	Set-up Time	Breakdowns	Planned Idle (lack of capacity & planned maintenance)
WELDING	hr.	hr.	hr.	hr.	hr.
FASTENING	hr.	hr.	hr.	hr.	hr.

24 hours

ASSEMBLY OPERATIONS AND EQUIPMENT:

	Welding	**Fastening**
Number of welds/ fasteners	# / part	# / part
Cost of added fasteners		$ /fastener
Stations per line		
Workers per station		
Set-up time	min. / lot	min. / lot
Line Rate	sec/part	sec/part
Cost of one fixture		
Number of fixtures		
Line Investment		
Building space per station	m^2	m^2
ASSEMBLY MAINTENANCE		
Total Annual expense for line	$ /yr	$ /yr
Total Annual building expense	$ /yr	$ /yr

PAINTING:

Operating Shifts ____hr.				**Non-operating Shifts** ____hr.
Parts Production	Breaks and Lunch	Set-up Time	Breakdowns	Planned Idle (lack of capacity & planned maintenance)
hr.	hr.	hr.	hr.	hr.

24 hours

PAINTING PRODUCT DESCRIPTION

Paint Cost	$ / L
Paint Transfer Efficiency	%
Paint Thickness	mm
Part surface area	cm^2
Workers per line	
Paint Line Rate	meters/minute
Hanger Spacing	meters
Parts per Hanger	
Cost of a Hanger	$ /hanger
Set-up time	min. / day

PAINTING EQUIPMENT

Conveyor Power	kW
Washer power	kW
Dip Tank Power	kW
Spray Booth Power	kW
Dryer Booth Power	kW
Conveyor System Investment	$
Washer Investment	$
Dip Tank Investment	$
Spray Booth Investment	$
Dryer Investment	$
Other Investment	$
Total Investment	$
Building Space per Painting Line	m^2

PAINTING MAINTENANCE

Total Annual machinery expense	$
Total Annual building expense	$

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