Inventory Control Strategies for Steel Industry Supply Chain

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A thesis submitted in partial fulfilment of the requirement of Sheffield Hallam University for the degree of Master of Philosophy

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'Inventory Control Strategies for Steel Industry Supply Chain'.

This thesis was submitted as requirements for the fulfilment of an MPhil award for the late Mr. Ahmed Basyouni. Mr. Basyouni obtained his MSc from the School of Engineering, Sheffield Hallam University UK in 1998 in Materials Science. Shortly afterwards he started his work towards a PhD degree in the split-time study mode at the Sheffield Business School, Sheffield Hallam University. Unfortunately soon after submitting his MPhil transfer report earlier this year (2001), he passed away while undergoing a back operation. In May 2001, Sheffield Hallam University took the view that the submitted work had made a substantial contribution to the body of knowledge and therefore should be brought into the public domain. His thesis was subsequently submitted for a posthumous MPhil award subject to the university's internal and external examination procedures.

Acknowledgements

Eman, the wife of late Mr. Basyouni has recorded her appreciation and acknowledgements to many people who have contributed in this process. Eman has spoken of her feelings about the long hours of dedication of her late husband, as this research work meant so much to him. On many occasions the late Ahmed Basyouni had spoken to me of his appreciation for his wife Eman, his son Malak, his parents and other family members, his friends including Karim and Saeed, Mr. Turkie and other staff of his company ANSDK in Alexandria Egypt, who had enabled his research to continue.

Personally I have lost a dedicated researcher in Ahmed, a sincere colleague and above all an excellent human being who had so much to offer to this world in his young age;

-- may his soul rest in peace--.

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1. AIMS AND OBJECTIVES

1.1 Aims

Slack (1998) defined inventory, or "stock", as the stored accumulation of material resources in a transformation system. In many industries such as steel, value of inventory is relatively small compared to the costs of the total inputs to the operation. In ANSDK (our case study) the situation is different where the inventory value is so high comparing with the total cost of the inputs (as it will shown in 3.8). The project target to decrease this value as much as possible to improve the company performance.

The supply chain to be investigated the supply reinforced steel bars to the construction industry. The end customer in the chain is usually a project management team, which comprises clients, consultant and contractors. The stockholders buy and stock large quantities. The behavior of the stockholding echelon causes rapid changes in the demand inflicted on the other members of the chain. The steel market is speculative and it is believed that the demand for construction products depends not only on the customer/contractor but also on other factors such as raw material, interest rates and delivery times. The reinforcement industry is recently been changing its order policy resulting in more unpredictable behavior. The reason is that stockholder target levels have been lowered due to economic changes affecting their business environment. As there is a natural tendency to minimize "buffer" or "safety" inventory in a recession the risk of running out of the stock increase.

The maintenance (repair/rework) environment in a company is usually characterized by stochastic demand, stochastic lead-time, and multi-item inventories. Consequently many current methods for determining optional stocking quantities are based on the assumption that parameters are known deterministically. Although sensitivity analysis has been performed on inventory models in stochastic environments, there is need to adequately address the effectiveness and sensitivity of various inventory models and related parameters to redesign inventory control strategies for spare-parts.

1.2 Objectives

Phase I (Mphil)

- To review supply chain modeling methodology in the steel industry, especially the spare parts inventory.control system
- To conduct a case study using a number of system dynamics techniques such as system input-output analysis, flow charting, and material & information flow analysis.
- To establish value added and non-value added analysis of the case study company by taking into account relevant labour, machining and energy consumption costs.
- To develop a spread-sheet model to be utilised as a static benchmarking tool by the management.

Phase II

- To develop conceptual and analytical models for inventory control strategies
- To confirm the validity of proposed models via statistical/computer simulation analysis and to compare the operational performance of various plants.
- To suggest the dynamic behaviour of the steel industry spare parts supply chain and re-engineering strategies (e.g. how to move more rapidly towards a Minimum Reasonable Inventory (MRI) scenario in the presence of capacity constraints, breakdowns and material supply lead-time bottlenecks).

1.3 Research Methodology

The research work is conducted by adopting system dynamics framework described by Hafeez *et al.*(1996) and illustrated in Figure 1.1 It has been successfully used for modeling and analysing a number of supply chains. Essentially the framework consists of two overlapping phases, namely qualitative and quantitative. The qualitative phase is related to acquiring sufficient intuitive and conceptual knowledge to understand the structure of inventory control strategies whereas the quantitative phase is associated with the development and analysis of simulation model. The main stages involved in qualitative phase are system input-output analysis, conceptual modeling, and block diagram formulation. The first step towards the quantitative model building is to, transform the conceptual model into a block diagram. In this format the flows of information and materials are to be represented via various paths. Production, ordering and other physical/ administrative operations are to be represented using blocks. The simulation model is to be verified by relevant personal and validated against field data. The deliverable of this project would be the analytical/computer models, which would provide guidelines for re-engineering spare parts inventory control strategies in a real company.

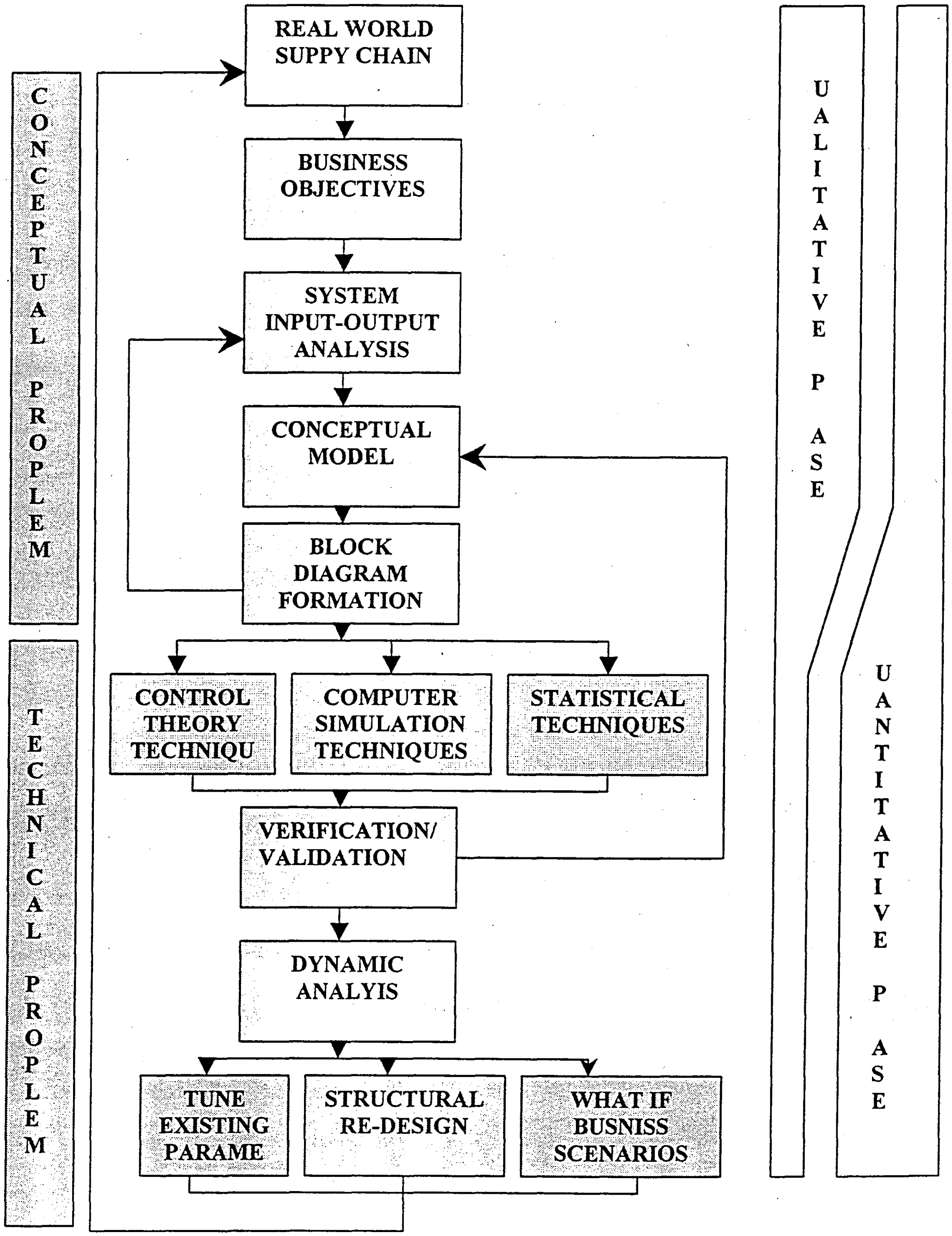

Figure 1.1 Integrated system dynamic framework for supply chain design (K.Hafeez *et-al.* 1996)

2. LITERATURE REVIEW

2.1 Re-Bars World Steel Market

In a recent study about re-bar steel market, IISI (1999) (International Iron & Steel Institute) statistics indicate that world re-bar output reached 107.463 million tons in 1998, increasing from 101.4 million tons in 1996 as shown in Figure 2.1. Before the Asian crises, the estimation for the growth of the world steel industry in the years from 1995 to 2010 was an average of 1.8% p.a. (Wodlinger 1999). This would have resulted in a global crude steel production level of approximately 980 million tons as compared to 753 million tons in 1995. This meant that growth would have been twice as strong as in previous 25 years. According to Wollinger (1999) Asian crisis may significantly affect the steel demand levels in all of Asia in 1998, which dropped by 10%, or 32 million ton/year of steel compared with 1997. But in a global level this was partly compensated for by growing steel markets in Western Europe and North America.

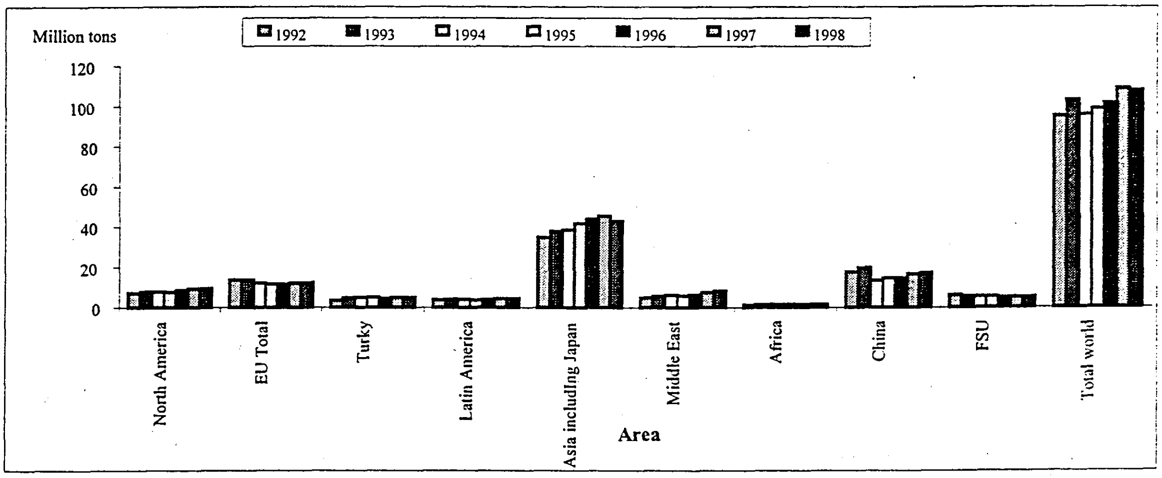

Figure 2.1 World steel production (IISI, 1999)

After the recovery of the Asian economy the normal steel growth path can be expected to continue. Steel analysts agree that the Asian crisis will not affect the long-term perspective for steel. Some are even inclined to believe that after the year 2000, steel growth will be even faster than originally predicted (Wodlinger 1999). Analysts have been saying that steel at present has utilized only 20% of its theoretical market, potential. In order to fully utilize this potential the quality of these steel products will be of decisive importance. Essentially the mechanical properties such as thickness, strength, and defect-free surfaces will determine the competitiveness of steel versus alternative materials (Wodlinger, 1999).

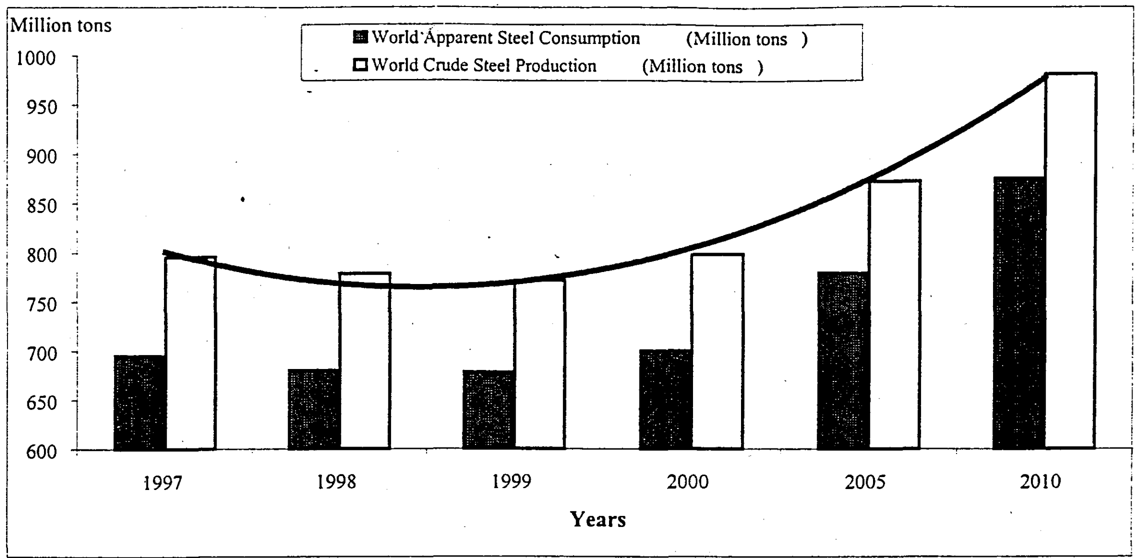

Figure 2.2 Estimated world steel consumption and production till year 2010 (Wodlinger, 1999)

2.2 Middle East Steel Market

Buxton (1999) reported that the Middle East, re-bar production reached 8.11 million tons in 1998 compared to 6.4 million tons in 1996.This increased was largely driven by Egypt, where the Egyptian production increased by 1.6 million tons during the last two years (See Figure 2.3). Lachgar (1999) has pointed out that, up to 1997 there was a boom in the Middle East production, doubling the output 1991 to 1997. The Middle East market was considered one of the most expanding markets for steel production, an industry evolved to replace imports.

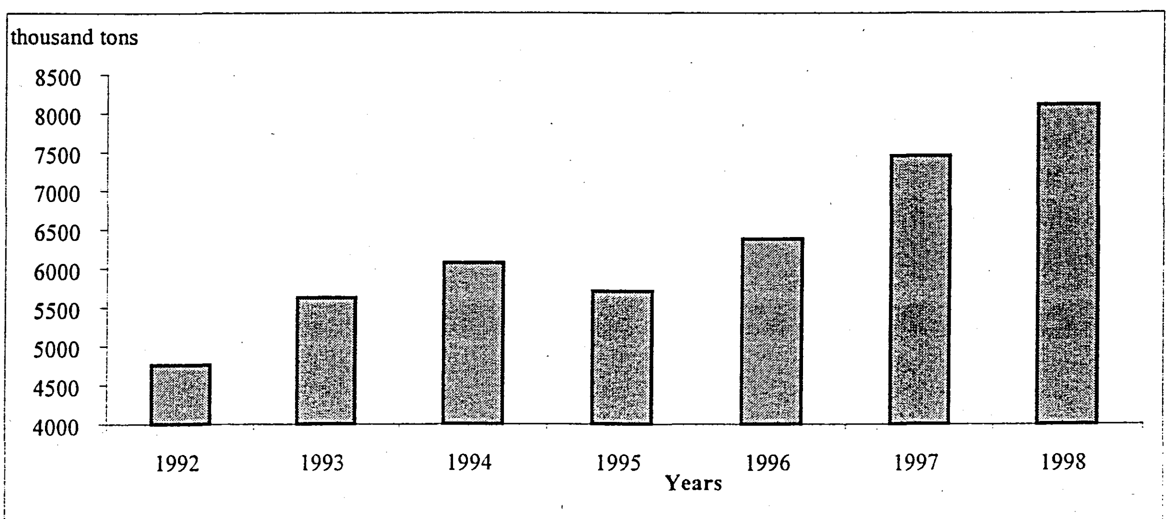

Figure 2.3 Middle East re-bar production volume (Buxton 1999)

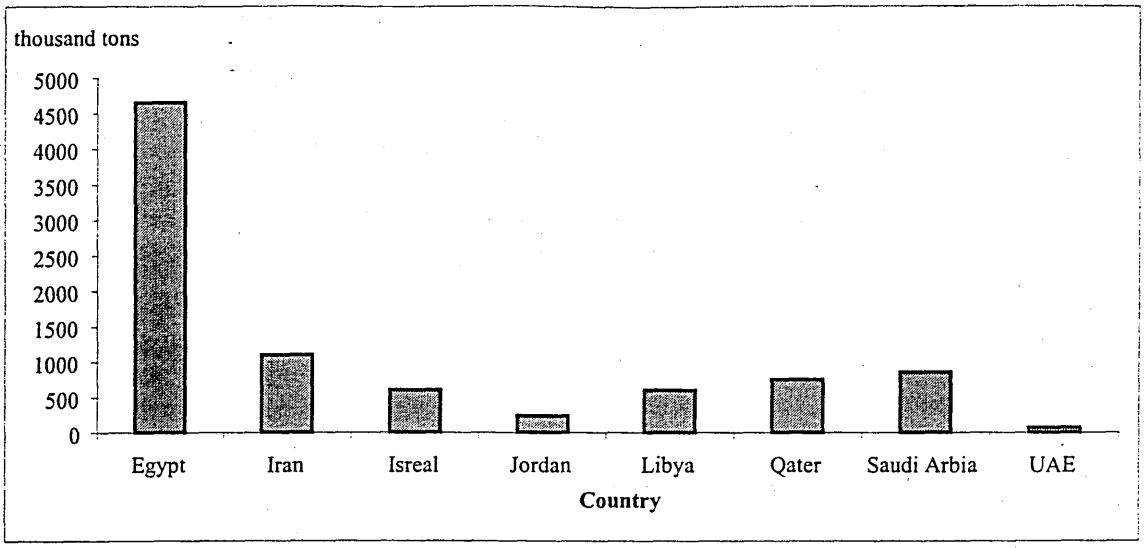

Figure 2.4 The biggest re-bar producer in the Middle East (Lachgar 1999)

2.3 The Egyptian Re-Bar Market

Figure 2.4 shows that Egypt is the biggest re-bar production in the Middle East market. The Egyptian market for long product is largely dominated by reinforcing bar, which is aimed at serving the country's construction industry. Figures 2.5, 2.6 and 2.7,respectively, show the total amount of import, the export, and the production, and consumption of re-bars since 1990.

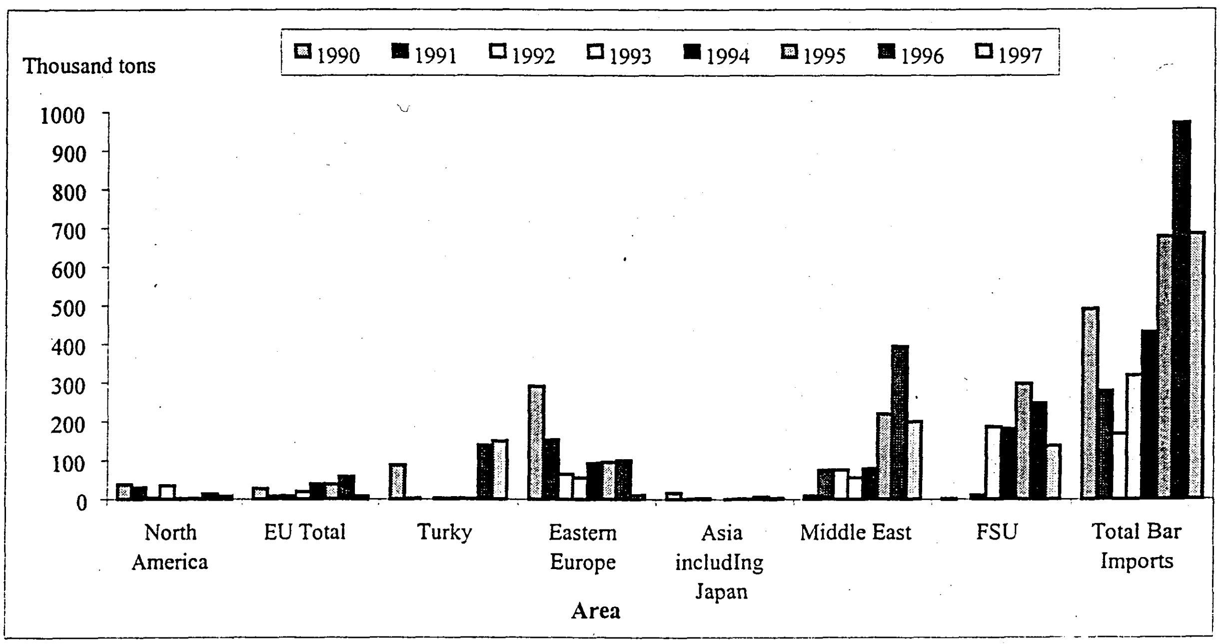

Figure 2.5 Egyptian imports of all re-bars

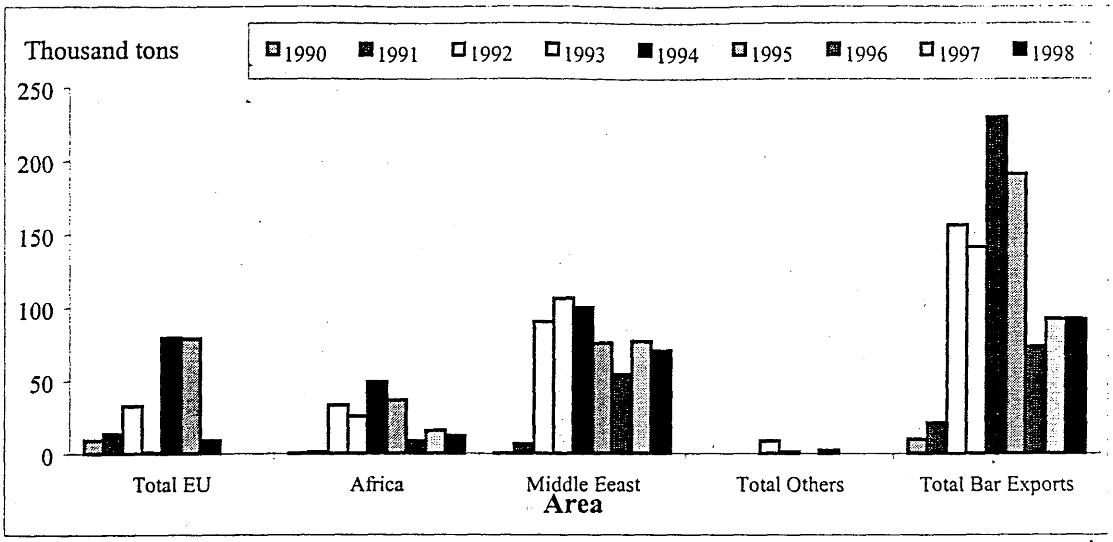

Figure 2.6 Egyptian exports of all re-bars

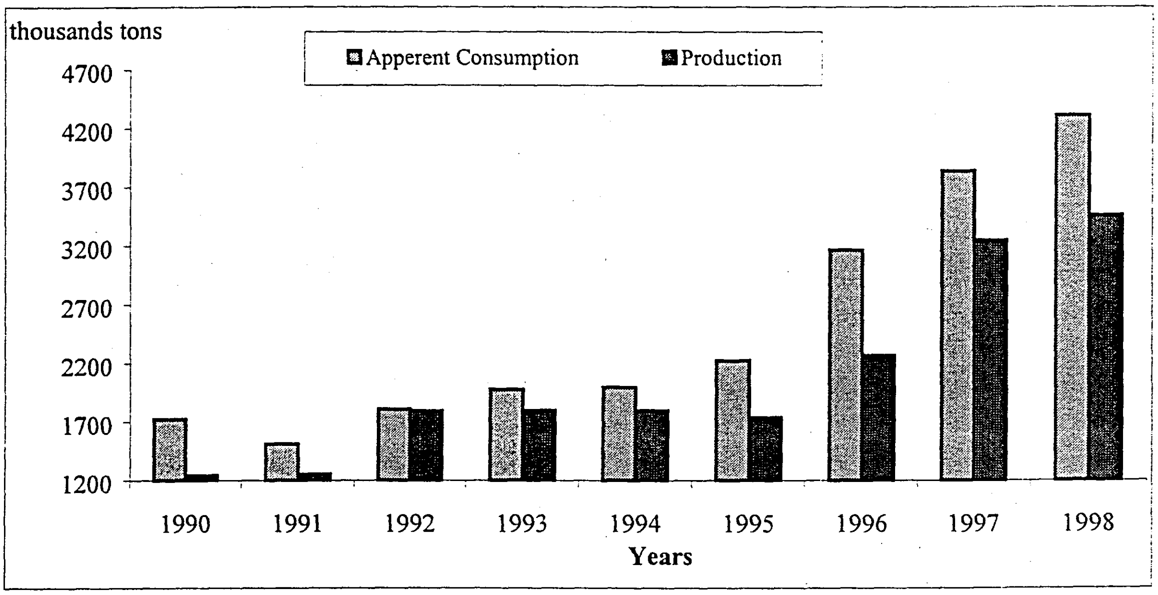

Figure 2.7 Egyptian re-bar production and consumption

Also Buxton (1999) mentioned that, total re-bar capacity in Egypt is estimated around 4.5 million ton/year, with further expansions of 400,000 ton/year planned to cover the difference between re-bar production and consumption. Long products have traditionally been the dominant part of the steel sector in the region. Re-bar production in Egypt reached 3.2 million tons during 1997, indicating a capacity utilization of 85.5% rising to an estimated 3.8 tons (86%) in 1998.

According to El-Nozahy (1999), privatization program is now being adopted by the Egyptian Government to sell the proportion of the steel industry in Egypt that remains under the control of HCMI (the state Holding Company Metallurgical Industries). The Egyptian industry has two main integrated steel producers, one is public and the other is private sector, there is semi-integrated public sector incorporating three mini- mills of different sizes, and also a number of independent private sector re-rollers located throughout the country.

There are several studies conducted on estimating future demand for steel production in Egypt by experienced foreign offices as well as Egyptian experienced office (Egitalec) however with common findings (El-Nozahy). A number of statistical analysis were carried out to project the Egyptian steel demand as shown in Figure 2.8. Growth rates and estimating for demand, is ranged between 5% and 7% annually.

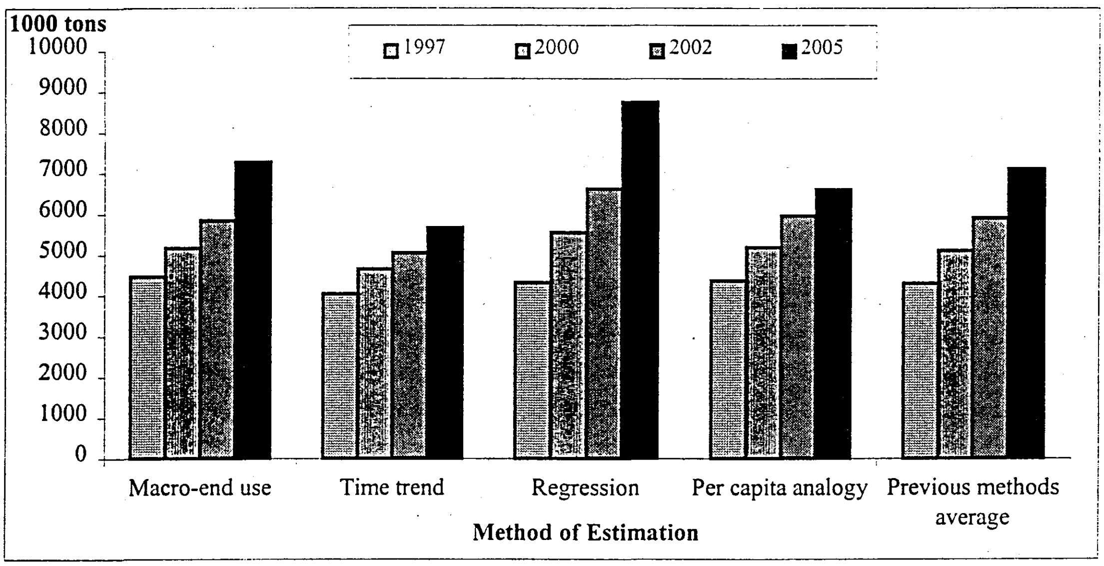

Figure 2.8 Future Egyptian demand of steel (El-Nozahy, 1999)

Fowler, (2000) has pointed out that, while analysts are not quick to predict what the world market for iron and steel will be in the near future, Egyptian companies should do all right with growth essentially ensured by the expansion of economy. There are major demands from new heavy metal construction such as Cairo Metro system, the Toshka land reclamation project and the new industrial zones. But according to the Inert Capital Securities, "demand for steel will be driven by increases in housing to accommodate the rapidly growing population and to replace old residential areas" (Fowler, 2000).

2.4 Discussion

From the world, Middle East, and Egyptian steel market survey, it is clear that there is severe worldwide competition. In-spite of a negative gap between Egyptian re-bar production and consumption, we see that the world wide steel production is more than consumption (see Figure 2.2) which would create a severe competition even in Egyptian market. Customer satisfaction has become a crucial factor for a company faced with this worldwide competition. The best way to increase market share is to offer low cost, high quality products. Supply chain management can be one way of achieving these performance criteria.

2.5 Inventory Management

Slack (1998) defined inventory, or "stock", as the stored accumulation of material resources in a transformation system. In many industries such as steel, value of inventory is relatively small compared to the costs of the total inputs to the operation. In others, for example automotive industry, it will be far high compared to its day-to-day expenditure on such things as labour, rent and running costs.

2.5.1 Type of inventory

Slack (1998) classified inventories under the following categories:

- Buffer inventory is also called safety inventory, its purpose is to compensate for the uncertainties inherent in supply and demand.
- Cycle inventory, it occurs because one or more stages in the operation cannot supply all the items it produces simultaneously.
- Anticipation inventory, it was used to compensate for the differences in the timing of supply and demand
- Pipe line inventory, it exists because materials cannot be transported instantaneously between the point of supply and the point of demand.

Also he categorized inventories regarding storage as follows:-

- Raw materials,
- In-process stock,
- Finished products,
- General stores, and
- Spare parts.

2.5.2 Inventory cost

Waters (1992) mentioned that most organizations view stock as a strategy to smooth out business. The strategic issue is how to minimize the stock cost and increase the customer services. Traditionally, companies satisfy their customer's demands through building up high stock levels. Such strategy has an advantage of quick response to the customer orders. On the other hand, it has an obvious disadvantage of having money tide up in stock. If the stock is not managed properly, the costs can become excessive and can reduce the ability of the organization to gain a competitive advantage in the market place. Holding excessive inventory implies high investment and drains more, cash. Also, low stocks leads to other implications - that is shortage, which can have high costs including the cost of losing the business. Waters classifies holding cost as follows:-

- **Unit cost**: is the price charged by the suppliers for one unit of an item, or the cost to the organization of acquiring one item.
- **Re-order cost:** is the total cost involved in placing a repeated order for the time. Each stage of order cycle carries fixed and variable cost component.
- **Holding costs:** is the cost of holding one unit of an item in stock for a period of time.
- **Shortage cost:** is the cost of loss of business.

Gattorna *et al* (1996) classify inventory-carrying costs as in Figure 2.9. This classification of inventory cost can be used for ANSDK especially for the spare parts inventory and that will enable us to know what is the main factors which affects the cost of this inventory.

2.5.3 Inventories in business organizations.

Sprague (1996) pointed out, while macroeconomists deal primarily with aggregated national inventory data, there are at least "five major components of inventory stocks. The three components of manufacturing inventories (raw materials and purchased parts, work in progress, and finished goods), plus the two trade components (wholesale/distribution and retail inventories). Inventory management and control are crucial to the firm because mismanagement of this asset can threaten the firm's existence. Through extensive literature review about inventory practice and control, Sprague concluded that, in general, inventories are controlled, not managed. Management would imply the establishment of strategic objectives and positioning for inventories. Control is the detailed set of activities surrounding the order practices of individual inventories items. So, if inventories are not managed at the strategic level within the firm, how are they planned and controlled? Throughout the inventory chain - raw materials and purchased parts to WIP to finished goods to distribution to retail. Inventories are planned and controlled item by item. For each item in an inventory, two questions must be answered again and again.

- How much should be ordered?
- When should it be ordered?

A medium-sized firm will typically have hundreds to several thousands of individual inventory items. The answers of the above two questions are determined every day for all of these items. The firm's inventory level is the aggregated result of these individual decisions made on the thousands of single items. Inventory planning systems at a firm are comprised of procedures intended to help answer the two questions, how much? And when? By using standard computer-based production-inventory control software package, like EOQ/R, MRP, and JIT systems. Small (1998) mentioned that the main goal of any warehouse should be to eliminate as much inventory as possible. A step toward achieving that goal is to begin thinking about how to move product out the warehouse door before it evens arrive. Warehouse management systems and inventory control systems shouldn't be confused. Ballard (1996) shows as in Figure 2.10 a typical supply chains configuration. Inventory management is concerned with the control of stocks through out the whole supply chain. Inventory monitoring and measurement takes place at each point in the supply chain.

Tomlinson (1994) has defined four levels of business control as shown in Figure 2.11. Inventory control sits at the data level where the day-to-day business is organized. Activities here are data driven and are primarily concerned with short term planning and recording of events. Inventory control is concerned with maintaining the correct level of stock and recording its movement. It deals mainly with historic data. Warehouse management sits at the execution level and is concerned with the activities within the warehouse and for making the best use of the resources (capital and human). In most cases a warehouse management system needs to be linked to an inventory control system but the converse is not true. This Business control hierarchy, which is shown in Figure 2.11, expresses ANSDK business control system except that production planning is responsible for inventory management (raw materials, primary and secondary products and final product) besides production planning. That may help more the planner to prepare adequate plans for production, where he has all the information about the inventories and production plants, and that helps in avoiding over or shortage stock.

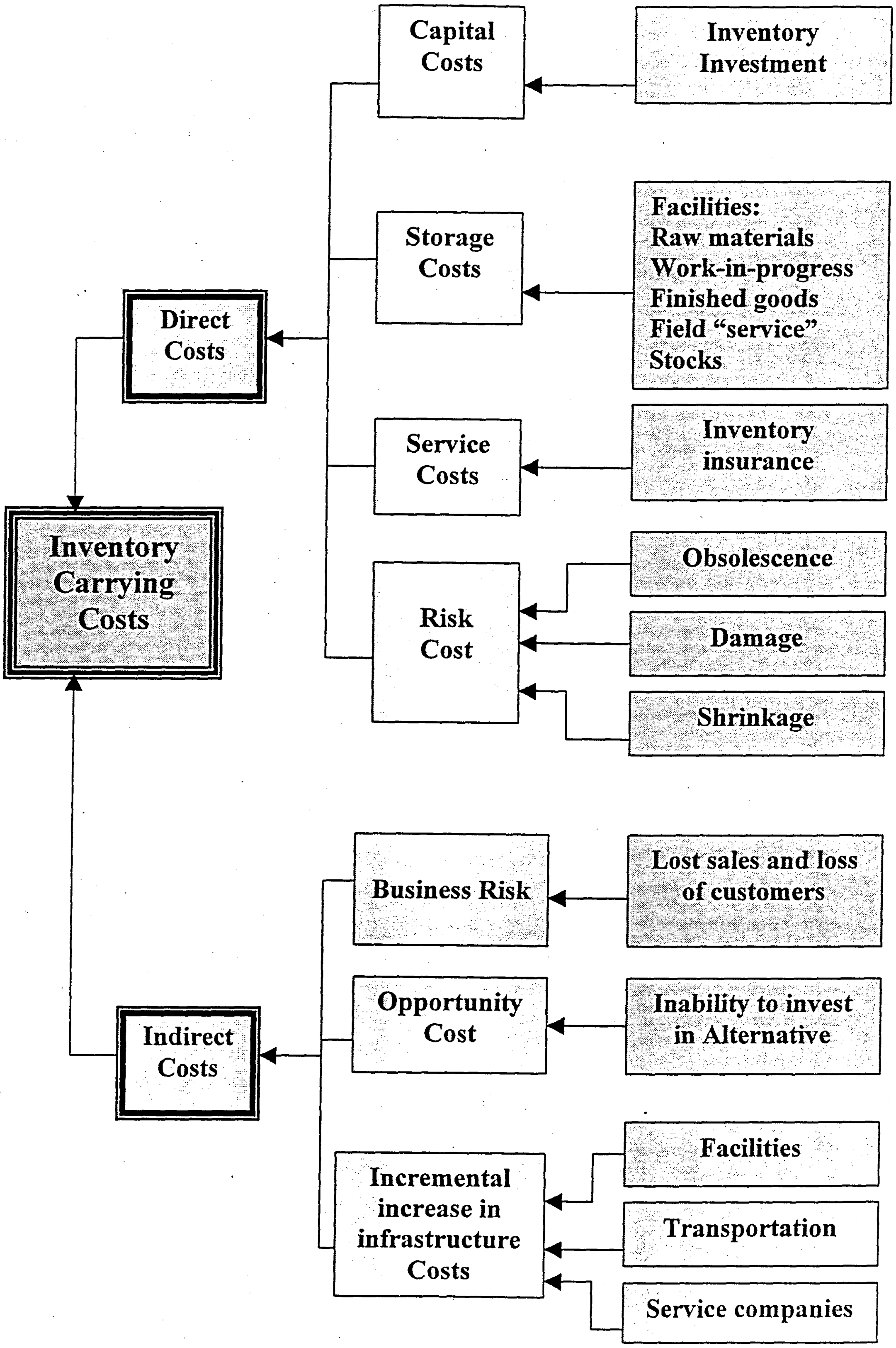

Figure 2.9 Inventory carrying costs (Gattorna el al, 1996)

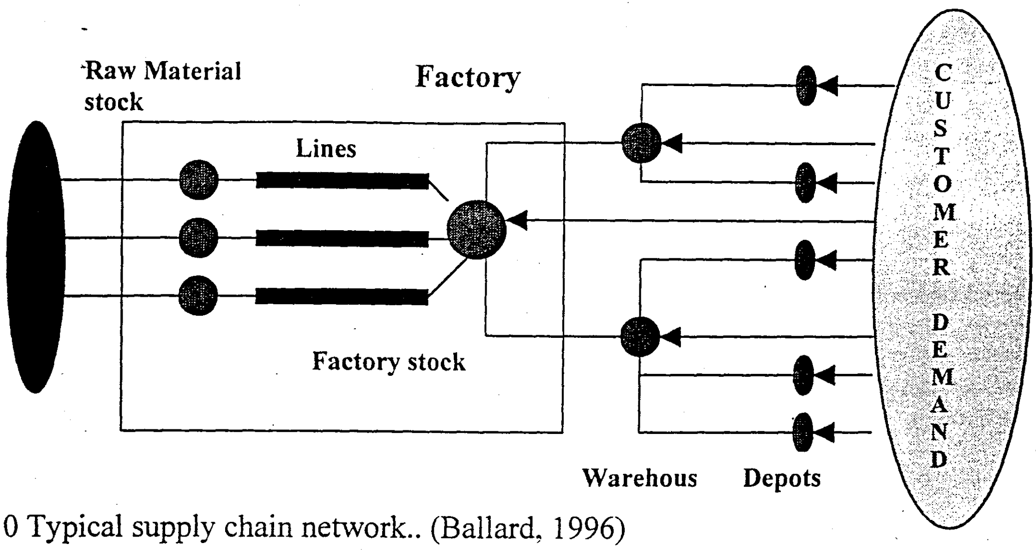

Figure 2.10 Typical supply chain network.. (Ballard, 1996)

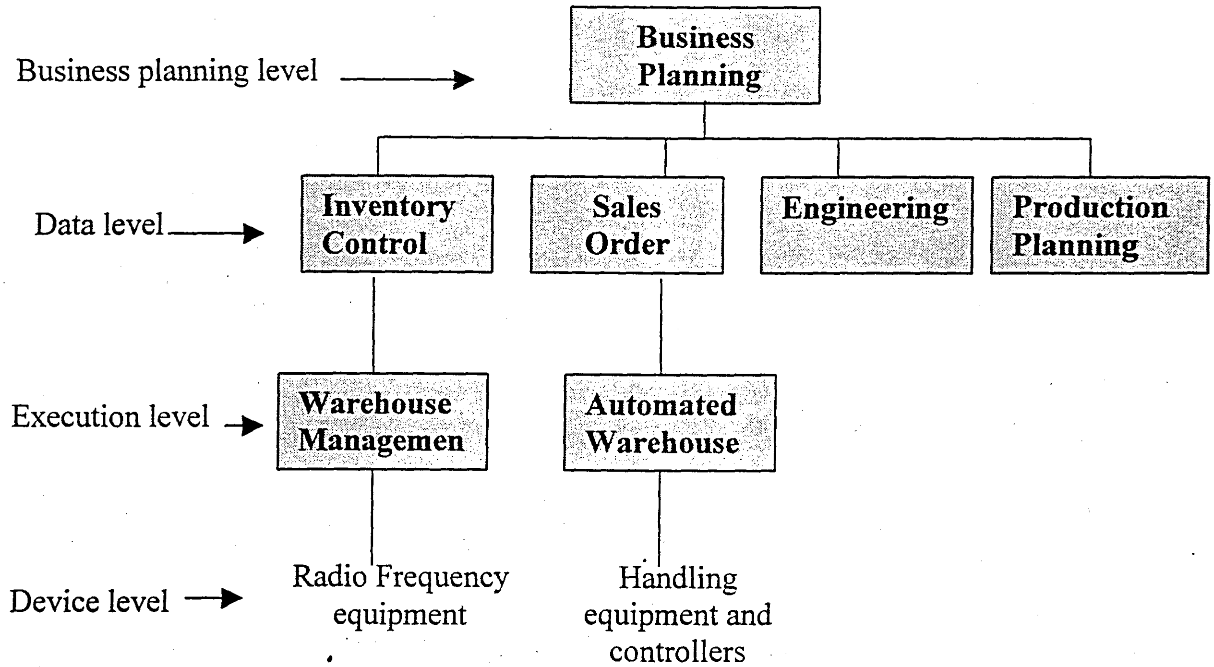

Figure 2.11 Business control hierarchy.(Tomlinson, 1994)

2.5.4 What has to be monitored and measured?

Ballard (1996) answered this question by a number of ways in which stock information can be categorized in order to describe the properties, status, quantity and location of a product, the stock information can split into three main categories, as shown in Figure 2.12.

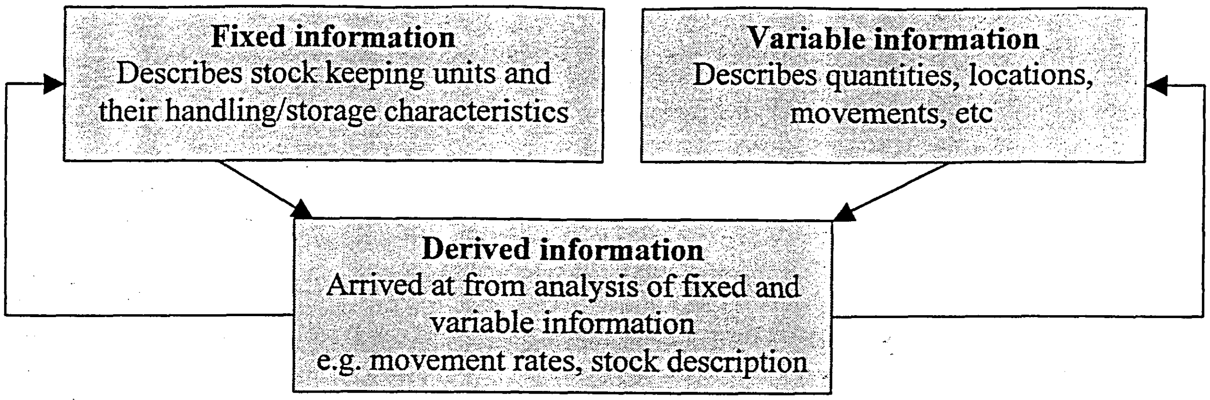

Figure 2.12 Inventory information. (Ballard 1996)

The better the monitoring of the process and the faster the information processing, then in principle and everything else being equal, the better will be the utilization of space and resources in the warehouse; there will be fewer errors and better customer service.

2.5.5 Spare parts inventory.

Walker (1997) has mentioned that one of the most important decisions routinely faced by maintenance managers is the determination of the appropriate stocking level of spare parts. The decision on the initial number to purchase can be developed in one of two ways. First, one can assign a carrying cost to stocks of spares and a downtime cost to shortage of spares. The number of spares can be selected to minimize the expected total cost of carrying and downtime costs per period. However, estimating downtime costs is a difficult task. Second approach is adopted, namely to specify a desired reliability measure and then to select the minimum number of spares to satisfy the, associated reliability constraint. Walker (1997) developed very simple graphical implementation, as shown in Figure 2.13 and 2.14, aid for choosing the initial number of insurance type spares (Critical expensive spares, which have a high probability that they will not be needed during the system lifetime) to purchase for systems having a finite population source of part failures. In Figure 2.13 with reliability 90%, "v" (Mean re-supply lead-time/mean failure-free operating time) < 0.01 and number of machine if more than ten (Number of machines which have the same spare part), the number of insurance spare which should be purchased is one, but with increasing of "v", more than 0.01, the number of purchasing insurance jumps to two with decreasing the number of machines to less than ten machines. The effect of increasing the reliability from 90% to 95% is shown in Figure 2.14, as with increasing the reliability the numbers of insurance spare parts increase. The simplicity of the method is appropriate for the poor quality of available data and indicates the sensitivity of the decision to the ratio (mean re-supply lead time/mean failure-free operating time).

Walker model can be used for ANSDK to calculate how much buffer spare parts should be purchased. That may lead to save much money, where the determination of the quantity of buffer spare parts in ANSDK depends on the personal experience, which is changeable from one to another.

Fortuin and Martin (1999) have distinguished three control situations of spare parts:

- Spare parts to maintain the company's own (production) facilities and system.
- Spare parts to service (professional) systems installed at customer sites; and
- Spare parts to repair consumer products, at service workshops.

Botter and Fortuin (2000) have suggested an inventory management framework using consumption, response time and price variables dimensions. Inventory can be positioned into one of the eight segments as represented in Figure 2.15.

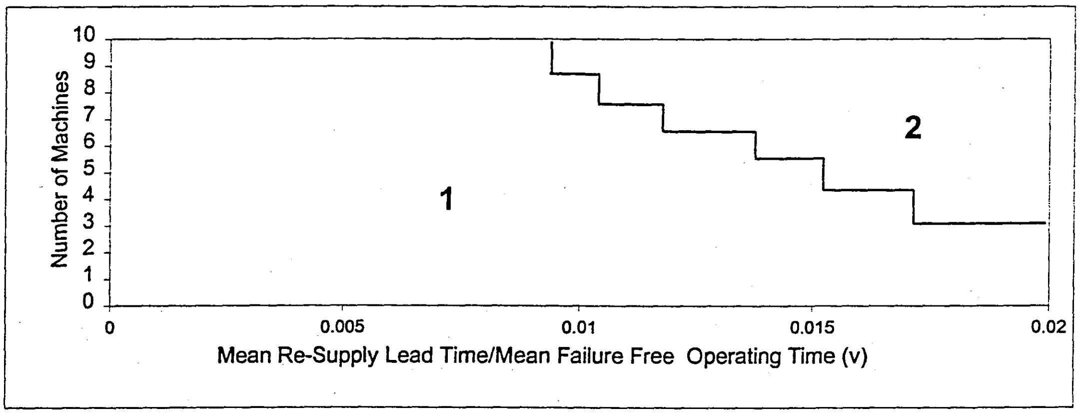

Figure 2.13 Number of spare parts for reliability of 90 per cent.

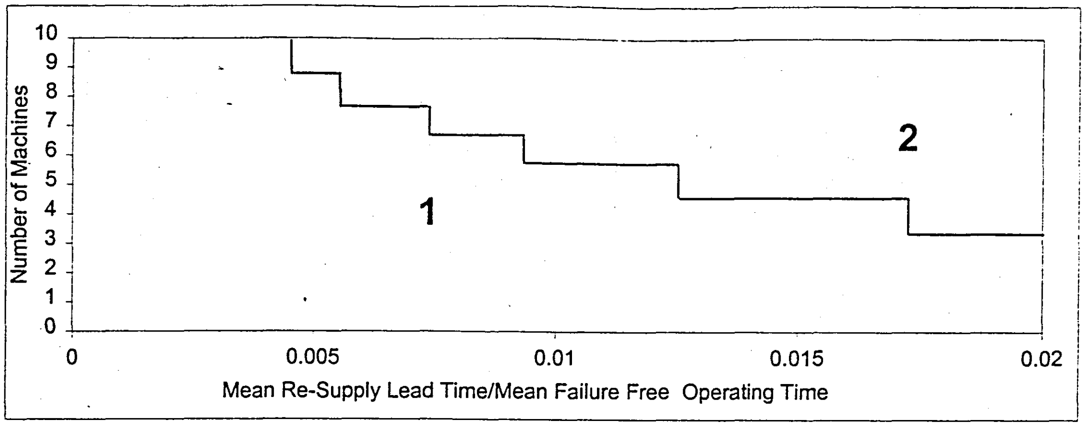

Figure 2.14 Number of spares for a reliability of 95%

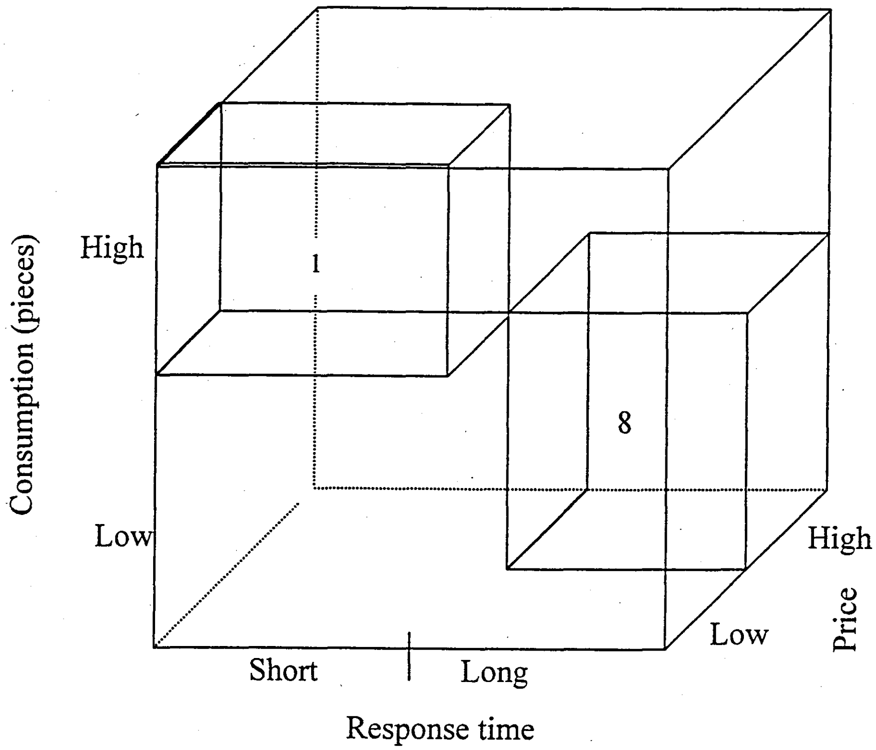

Figure 2.15 Example of framework depiction for consumption, response time, and price available (Botter, 2000)

1. Low price, short response time, high usage spare parts
2. Low price, short response time, low usage spare parts
3. Low price, long response time, high usage spare parts
4. Low price, long response time, low usage spare parts
5. High price, short response time, high usage spare parts
6. High price, short response time, low usage spare parts
7. High price, long response time, high usage spare parts
8. High price, long response time, low usage spare parts.
9.

By categorizing spare parts, which used at ANSDK according to these eight segments, which is manageable, will facilitate the decision making of when and how much of spare parts could be purchased. As example for segment one, these cheap, fast moving items have to be stocked in large quantity in the company warehouse, On the other hand the segment eight, these expensive, long response time and low usage spare parts, owing to long response time these items can be ordered regularly when needed. The same philosophy could be followed for other segments to determine the suitable decision.

2.5.6 Discussion

Fortuin 1999, found that service (spare) parts are needed for maintenance of industrial systems as well as for consumer products, and found their logistics has an inherent difficulty. Fortuin pointed out that common models for spare parts inventory management are invalid, as the demand process is different and demand data scarce. In this project we intent to built a system dynamic model for spare parts inventory management in steel industry. Botter (2000) mentioned that, spare parts inventories couldn't be managed by standard inventory control methods, as a condition for applying the underlying models are not satisfied. Nevertheless, the basic questions of inventory control have to be answered: which parts should be stocked? Where should they be stocked? How many of them should be stocked? Furtuin framework depiction for consumption, response time, and price variable, could be the starts point for classification the spare parts in ANSDK.

Of course, the improper management of spare parts leads to disturbance of production line if there is shortage from spare parts or overstock of spare parts. In both cases it will affect the performance of the company. So the spare parts have to be managed and stocked at appropriate points with appropriate quantity in the supply chain to guarantee a high service level with lowest stock from spare parts and that the aim for this project to build a modeling system can achieve this target. Where ANSDK is suffering from high stock spare parts inventory (as shown in 3.8.1) and it is really need this kind of methodology to sort out a problem of £90 million in the spare parts stock.

2.6 Supply Chain Management

During the last decade, supply chain management has made its impression both in academic and professional fields (Anderson 1999). Many companies have recognized the potential impact on their competitiveness and financial performance and have re-deployed their high caliber individuals in supply chain management positions. Supply chain management is much discussed in today's business world because it constitutes the conceptual base for the application of a host of new information and automation technologies. Used wisely, these new technologies are competitive tools for better determining demand, scheduling production, managing inventory, and speeding the order-fulfillment cycle. Therefore it is anticipated that excellence in supply chain management will lead to more satisfied customers and increased market share.

2.6.1 Supply chain definitions.

Slack (1998) defined supply chain management as the flow of materials and information through a business from the purchasing activity through the operation and out to customers, by way of a distribution or service delivery activity. It is defined also as a loop: it starts at the customer and it ends with the customer through the loop flows all materials and finished goods, all information, even transactions, it requires looking at a business as one continual process and further. This process absorbs such traditional distinct functions as: forecast, purchasing, manufacturing, distribution, sales, and marketing into a continues flow of business interaction. Stevens (1989) Defined the supply chain as the connected series of activates which is concerned with planning, co-ordinating and controlling material, parts and finished goods from supplier to customer. Beamon (1999) defined the supply chain as an integrated process wherein raw materials are manufactured into final products then delivered to customers (via distribution, retail, or both). Talluri (2000) defined supply chain management as coordinating and managing all the activities from raw materials procurement to the delivery of the final product to the customer. A key ingredient for effective supply chain is timely planning and information processing across the entire value-added chain. Lummus et-al (1999) coverd all the previous definitions and gave a summary definition for the supply chain which stated as all the activities involved in delivering a product from raw material through to customers, including sourcing raw materials and parts manufacturing and assembly, warehousing and inventory tracking, order entry and order management, distribution across all channels, delivery to the customer, and the information system necessary to monitor all of these activities. It links all of the partners in the chain including departments within an organization and the external partners including suppliers, carriers, third party companies, and information system providers.

Slack (1998) outlined the main objectives of supply chain management as follows: -

- To focus on satisfying end customers
- To formulate and implement strategies based on capturing and retaining end-customers business.
- To manage the chain efficiently

2.6.2 The seven principles of supply chain management

Anderson (1999) explains that to balance customers' demands with the need for profitable growth, many companies have moved aggressively to improve supply chain management. Their efforts may be summarized as the seven principles of supply chain management that, working together can enhance revenue, cost control, and asset utilization as well as customer satisfaction.

Principle 1: Segment customers based on the service needs of distinct groups and adapt the supply chain to serve these segments profitably.

Principle 2: Customize the logistics network to the service requirements and profitability of customer segments.

Principle 3: Listen to market signals and aligns demand planning accordingly across the supply chain, ensuring consistent forecasts and optimal resources allocation.

Principle 4: Differentiate product closer to the customer and speed conversion across the supply chain.

Principle 5: Manage source of supply strategically to reduce the total cost of owing materials and services.

Principle 6: Develop a supply chain-wide technology strategy that supports multiple levels of decision-making and gives clear view of the flow of products, services, and information.

Principle 7: Adopt channel-spanning performance measures to gauge collective success in reaching the end-user effectively and efficiently.

2.6.3 Some methodologies for investigating supply chain

Griffithin (1993) have proposed a manufacturing system design procedureas in Figure 2.16. It includes a detailed block diagram; based on the conceptual model that develops the mathematical relationships between the various interacting variables.

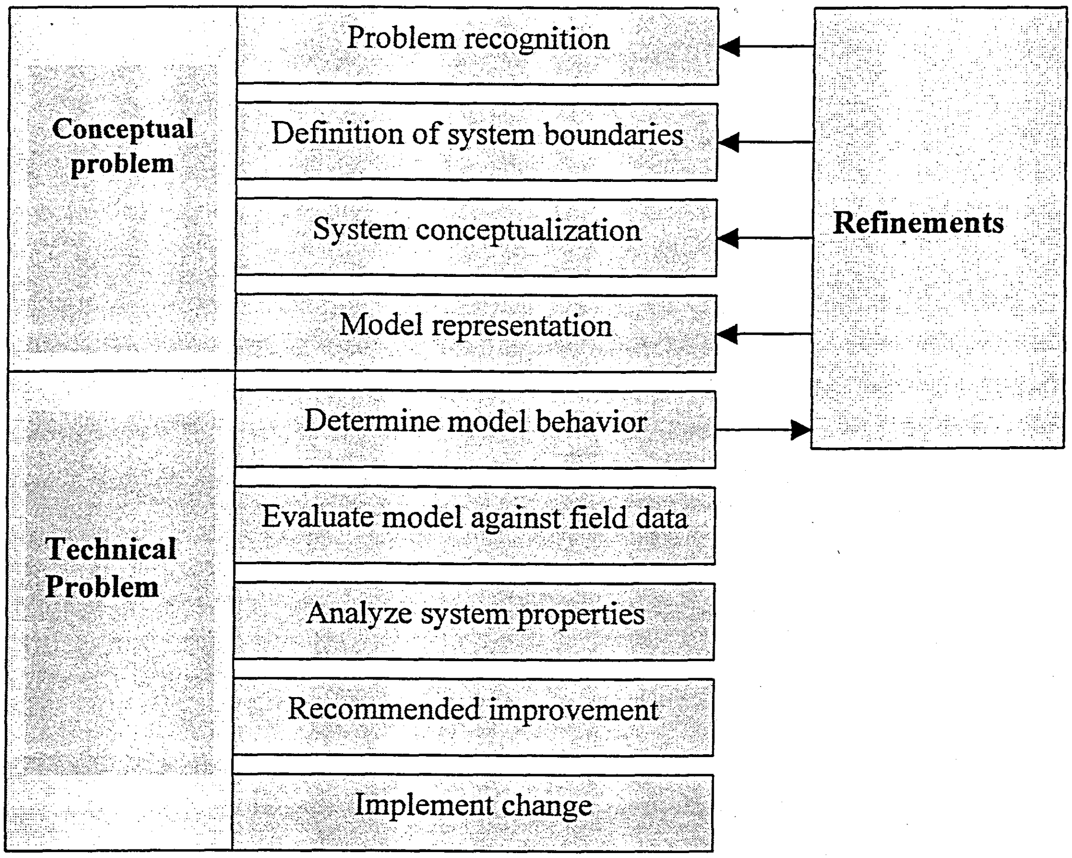

Figure 2.16 Essential steps in the modeling and design of manufacturing system (Griffithin, 1993)

This methodology was upgraded to another methodology called UDSO-BPR methodology. Waston (1994) has summarized UDSO-BPR (Understand, Document, Simplify, and Optimise- Business Process Re-engineering) system methodology to analyse the manufacturing system as follow:

Understand – defined the problem, system boundaries and performance matrices

Document-modeling an existing system is an important pre-requisite before any solution is implemented to set the benchmarks by which the solutions can be judged.

Simplify- eliminates waste in the model from waste time, waste materials, waste information, and waste capacity.etc. This stage of re-engineering program requires the formalizing of processes (via the flows within the system), which may have only previously been putative.

Optimise- once the processes have been identified and streamlined should "sophisticated" methods of control be applied to ensure their consistency and reliability. Methods include computer simulation, statistical process control, experimental design, and network analysis.

This methodology provided a structured and methodical way of analysing the company's manufacturing system and decomposing the problems encountered. By using this methodology for, Aerospace actuation system and electricity transmission networks, improves the manufacturing system performance include up to 75% Reduction in manufacturing lead times, 30% reduction in costs and 75% reduction in total inventor.

Again this USDO-BPR methodology was up-graded by K. Hafeez <u>et-</u>al (1996) to system dynamic framework (Figure 1.1). An important aspect of this methodology is to decompose a supply chain into distinct (preferably naturally existing) autonomous business units. This helps to simplify the designing task as conceptual and mathematical models for each unit are developed and analyzed individually. Aggregation of these models to represent a complete supply chain then follows. Essentially the framework consists of two over-lapping phases. Qualitative phase is related to acquiring sufficient intuitive and conceptual, knowledge to understand the structure and operation of supply chain, whereas, the quantitative phase is associated with the development and analysis of mathematical and simulation model.

WMC Company (It manufactures and distributes mechanical/electrical equipment for the construction industry) focused its improvement strategies on integrating its supply chain in order to maximize the efficiency of all internal and external operations. Lewis *<u>et-al</u>* (1997) used an integrated approach, which is shown in Figure 2.17, to re-engineering the supply chain process within the company, to achieve this target.

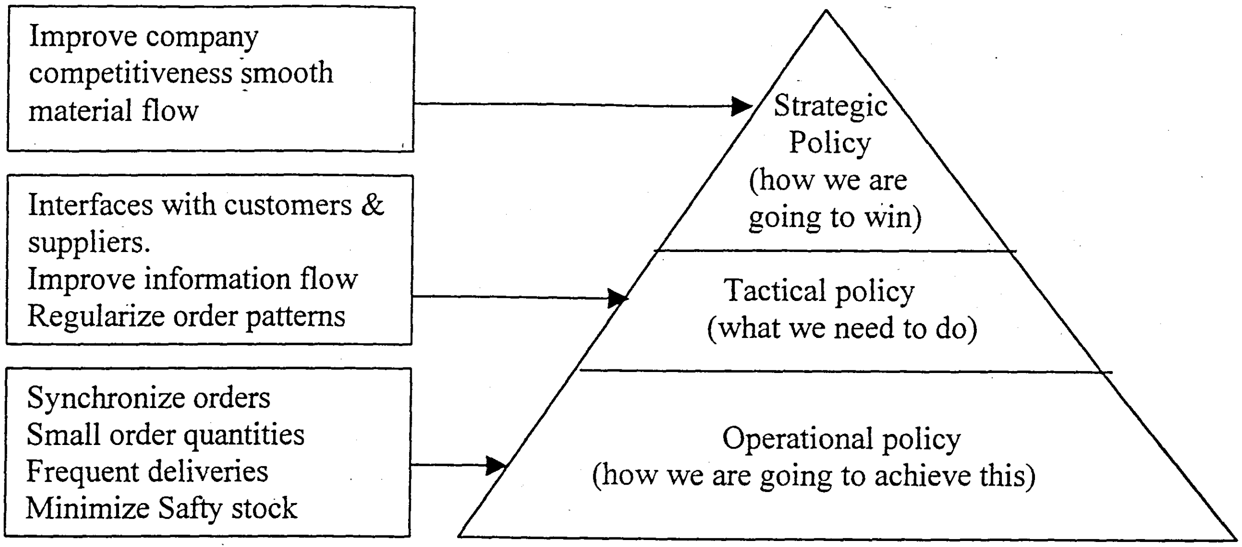

Figure 2.17 An integrated approach to re-engineering the supply chain interface (Lewis <u>et-al</u> 1997)

The first level of this approach is the strategic policy where the company identifies what they need, in WMC Company they need to improve company competitiveness via smooth material flow. The second level, the tactical policy, addressed the issue what should be done to achieve this target, like to getting closer to the suppliers to improve information flow. Finally, the third level, the operational policy, to propose the policy how to achieve this tactic, as an example in WMC case, in order to improve the detailed design of the reordering systems in operation, it was necessary to increase the frequency of the ordering and reduce the sizes of the batch quantities. This is where simulation of "what-if" scenarios was most useful in attempting to identify improvement prior to implementation.

By using this methodology, WMC learnt a number of lessons to be applied and improved its performance like, Simple statistical analysis coupled with simulation can predict the situation prior to implementation, Keeping the re-ordering policy simple and they should confirm the accuracy of information flow to reduce the effect of uncertainty.

Gunasekaran (2000) studied how to improve the operations performance in Valeo Company (automotive company), through the supply chain, to improve its productivity. The manufacturing system methodology which developed by Griffith (1993), was used:

- ➢ Monitor the process
- ➢ Record performance
- ➢ Analyse performance over time
- ➢ Propose solutions which include ideas for improvement, and
- ➢ Implement solution.

The following tools were used in order to improve productivity:

- ➢ Management of inventory
- ➢ Design and specification of the process
- ➢ Layout of the cells, and
- ➢ Design of jobs and work

The result of the improvement methods implemented could be determined through several ways. The introduction of the flute reduces the cycle time of the wet-setting process (process step on automotive company) while the development of autonomous cell improves the output/person calculated. This is based on figures used to determine the productivity of the factory and on time delivery. They succeeded to make a minor improvement in set-up time, which led to a considerable reduction in non-value adding activities in terms of using smaller lot sizes and making the production line "lean " to support JIT material flow in a manufacturing cell.

Lehtonen (1997), has developed a method as shown in Figure 2.18, this is based on controllability analysis theory, which is defined as the ability of a system to reach a certain state in a finite time span. The aim of this methodology is to reveal the potential improvement areas and define and analyse the data so that they ready for the simulation process. The simulation project steps of "problem finding" and the difficult matter of "data gathering and analysis" are reduced by means of controllability, analysis. The result of controllability analysis reduce the complexity of simulation modeling in three ways:

- The model building and coding effort can be reduced, because the simulation model can be focused directly on the key problem areas.
- The amount of data needed in the analysis can be reduced, because the multitude of the data can be replaced by approximations using zoom and focus methods. For example, instead of having all the products in the model, one can take the products that incur most costs. These approximations are not averages, but they are data units that represent the problem in the best way.

- The number of experimental and "what if" scenarios needing analysis are significantly reduced because the key problem areas have already been found by the use of controllability analysis.

This methodology was used successfully in analyzing and improving the logistics performance of paper mill, where a simulation model was build and new operation scenarios was introduced. The results of this case study allowed reduction in inventory levels with no negative effect on customer lead-time. Lehtonen mentioned that, the data for this methodology should be predominantly quantitative, to make the ordering of the potential improvement areas by their importance easier. The difficulty for this system increases with increasing the ordering of the potential. Comparing with the system dynamic approach, It was found that, this methodology is a part from system dynamic. In system dynamic we have another alternatives beside the control theory technique, that computer simulation techniques and statistical techniques which they can handle the complex equation (higher ordering potential) better than control theory.

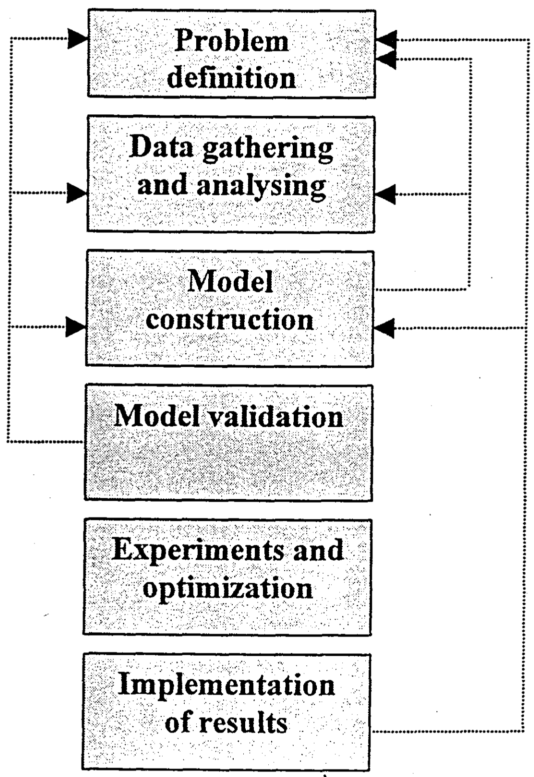

Figure 2.18 Stages of the methodology that depends on controllability analysis (Lehtonen, 1997).

2.6.4 Discussion

Grffiths and Hafeez (1993) have illustrated that the way in which a supply chain is structured is of vital importance to manage the individual businesses operating within it. The aim of all successful industrial companies must be to control production and distribution efficiently. In many industries the traditional strategy by which a company satisfies fluctuating customer demand is to keep high stock levels. This has the advantage of reducing the lead-time as perceived by the customer, but has the obvious disadvantage of having money tide up in stock. Therefore the aim of good management should be to reduce stock levels while maintaining or even reducing lead-times. These strategies would help companies to meet customers' demand of faster delivery and better service, in addition to low prices and high quality.

In ANSDK case low price strategy is very vital to survive the hard competition from local Egyptian and global market, especially Eastern European and China. Holding high level of anticipatory inventory may offer a way to avoid out-of-stock, but it is very expensive method of avoidance. Inventory management will be discussed in details in the next section.

System dynamic framework will be used as a methodology for this project, as it has been successfully used for modeling and analysing a number of supply chains as shown in 1.3 (Research Methodology). Comparing with another methodologies, we found that system dynamic framework, is more simple, detailed and arranged methodology, which facilitates the way of research and it gives three alternative to deal with the data, control theory technique, computer simulation techniques, or statistical techniques

3. CASE STUDY

3.1 ANSDK Company

During the era of nationalization launched by Gamal Abdel Nasser (1954-1970) and afterwards, Egypt was one of the world's biggest steel importers. ANSDK, now the largest steel in Egypt, became Egypt's first private sector steel company when it began producing steel in 1986. The aim was to produce 750,000 tons of steel reinforcing bars a year for the local use. ANSDK started as a joint stock company with 87% of its shares held by Egyptian investors, 10% held by a Japanese consortium and 3% contributed by the international Finance Corp. Initial capital was 233 million Egyptian pounds (£47.65 million). Today, ANSDK has 3158 employees. Currently it is spending £486.1million for construction and debt payments on a flat steel-making project. The new hot rolling plant was completed in April 2000. Financially, the expansion project has cost the company dearly. Its debt ratio is very high and interest payments on its debt soared 70% in 1999 to 194 million pounds per year (£39.6 million). The high debt, combined with low steel prices worldwide, led to a 59% decline in its 1999 earning causing EFG (Egyptian Finance Group) Hermes in February to issue a "reduce" recommendation on ANSDK's stock. EFG said it was issuing the recommendation "despite our expectation that the company will benefit from the increase in steel prices and our view that the acquisition of 28% of ANSDK by El-Ezz Steel Re-bars will be positive for both the companies" (Susan Flower 2000).

The plant melts the sponge iron produced in direct reduction plants, in addition to steel scrap and lime that is produced by lime calcining plant together with the additives materials. The melting plants consist of 4 electric arc furnaces 80 MT/heat each and two-ladle furnace for controlling chemical composition. The capacity of the four electric furnaces is 1,555,200 metric tons/year of molten steel. Three casting machines at a total capacity of 1,532,000 metric tons/year continuously cast the molten steel. There are three separate plants for rolling steel billets; two produce steel bars at production capacity of 920,000 tons/year and the other plant for producing wire rod through two identical strands at a production capacity of 804,000 tons/year. Figure 3.6 shows the flow of the materials inside ANSDK, starting from raw materials supplier passing through Direct reduction Plant (DRP), then to Electric Arc Furnaces (EAF) and Continuous Casting Machine (CCM), finally either to Bar Mill or to Rod Mill depend on the customer requirements.

Figure 3.1 shows the ANSDK production activities, sales activities, and exporting activities since start up 1986. It is clear that ANSDK developed itself and increased its capability to produce high quality and cheap price re-bar to compete in Egyptian and international market. Table 3.1 also expresses the ANSDK's comparative basic data during the last 5 years. And that is clear that the net profit of 1998 decreased by ~ 42% comparing with 1997, because of steel market as we describe in 2.1, 2.2,and 2.3.

ANSDK reported that 1998 sales volume recorded 1.453 million tons out of which 1.183 million tons directed to the local market sharing by 33% of its needs. In addition 270 thousand tons exported to international market giving £50 million as export revenues. The increased imported quantities of re-bars especially those of CIS origin at shrink prices coincided with the international economic depression had its negative effect on the sales prices locally and internationally. Consequently the company's sales revenues stood at £0.3 billion.

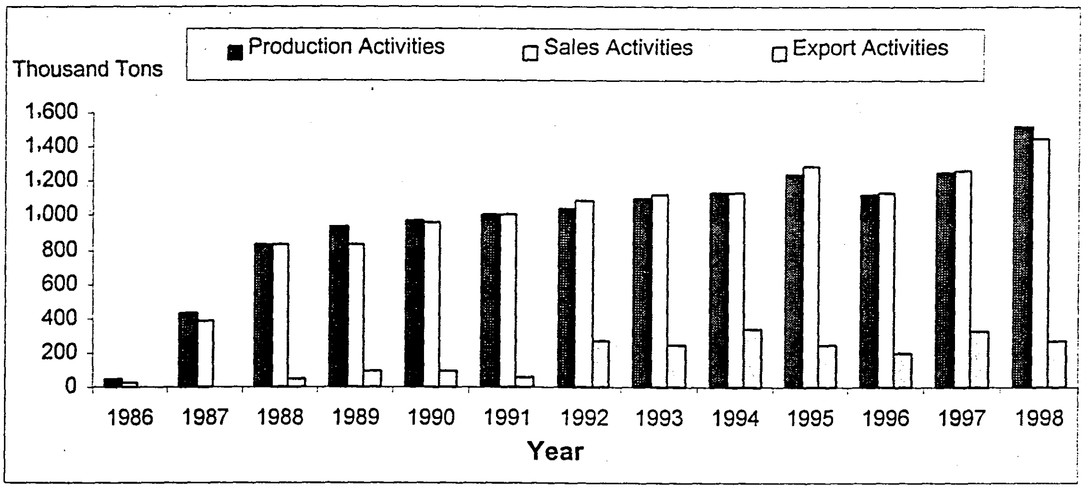

Figure 3.1 ANSDK production, sales, and exporting activities

Item	Unit	1995	1996	1997	1998
Production rate	In 1000 tons	1234	1119	1244	1516
Sales Quantity	In 1000 tons	1280	1128	1266	1453
Export Quantity	In 1000 tons	250	203	328	270
Average price of Export	In £/ton FOB	198	186	185	180
Net Profit	In Million £	24.6	25.1	24.7	14.5
The productivity/worker	Tons	509	461	484	543

Table 3.1 ANSDK's activities comparative basic data (ANSDK 1998 annual report)

ANSDK is considered the second biggest steel producer in Arab world and the following Figure 3.2 shows the production and exports of the Major Arab steel companies during 1997 and 1998. (Lachgar, 1999)

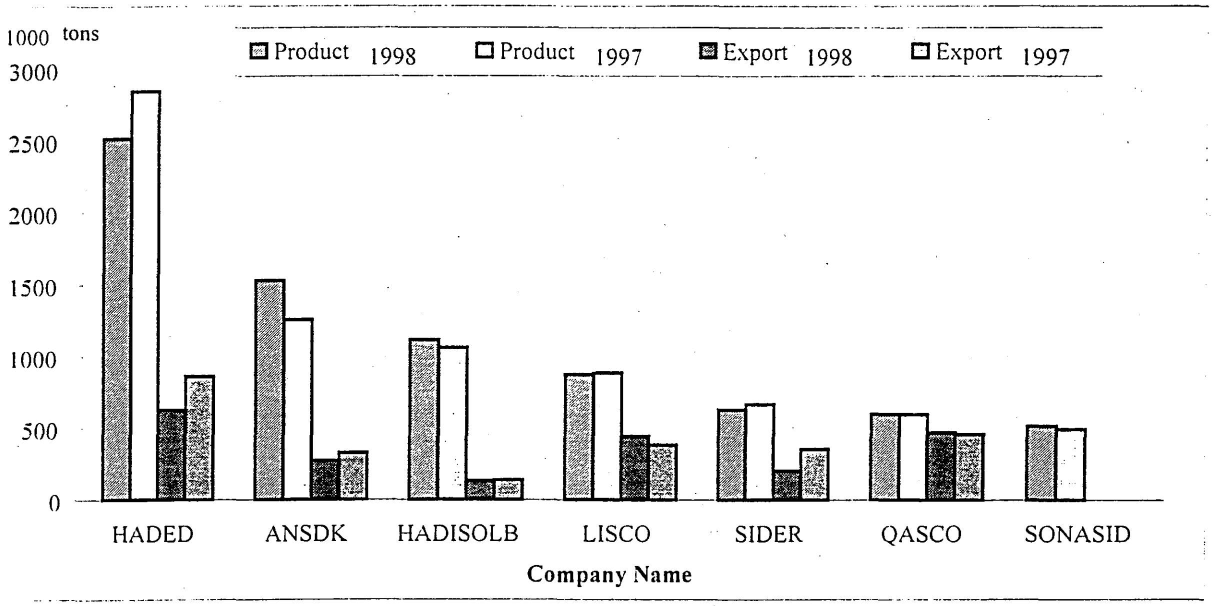

Figure 3.2 Evaluation of production and exports of the major Arab steel companies during 1997 and 1998. (Lachgar, 1999)

ANSDK is considered one of the biggest steel producers in Egypt (Reinforced and flat steel). Figures 3.3, 3.4, and 3.5 show the profile of this company in the Egyptian steel market. It has exported 20% of its production for years, a move that ensures it foreign currency needed to offset its import bill.

Now the company strategy is to move to the flat steel production. Recently ANSDK has started a new facility to produce one million tons hot rolled coils with coil weight 28 tons maximum and thickness range of 1.2-13 mm and width range of 900-1600 mm. It has now signed a contract to export 120,000 tons of flat steel at £201 per ton. The company expects to produce 400,000 tons of flat steel in 2000, with more production coming on line in the next two years.(Gunter 1999)

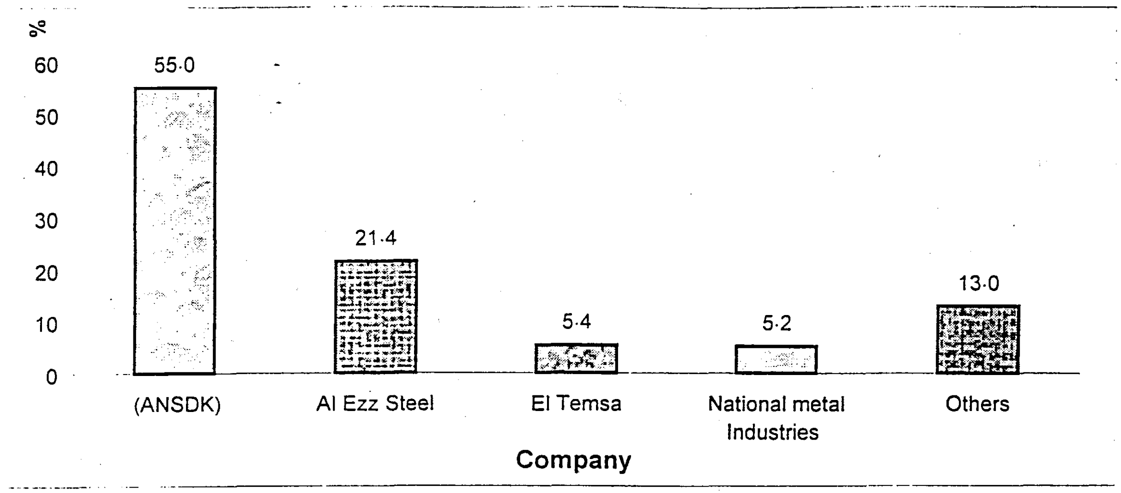

Figure 3.3 Total Egyptian market shares in 1997 (Buxton, 1999)

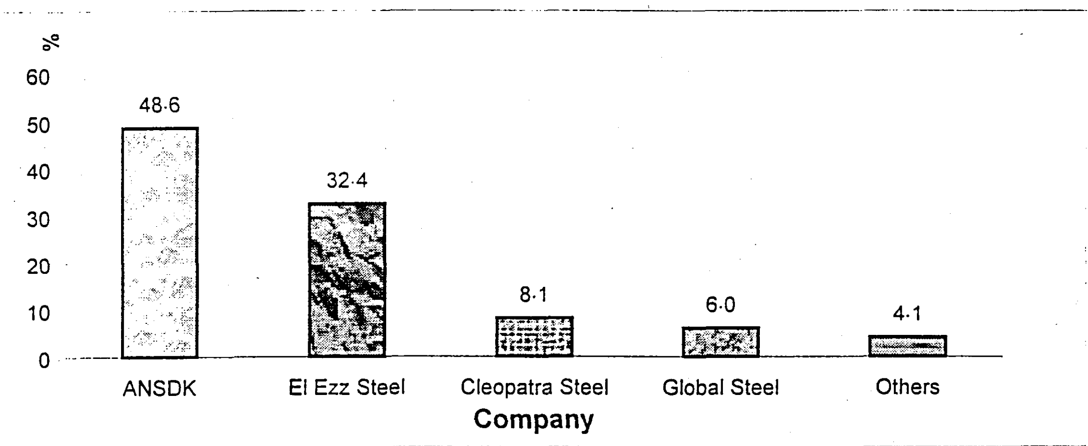

Figure 3.4 Projected Egyptian re-bar market in 2001(Buxton, 1999)

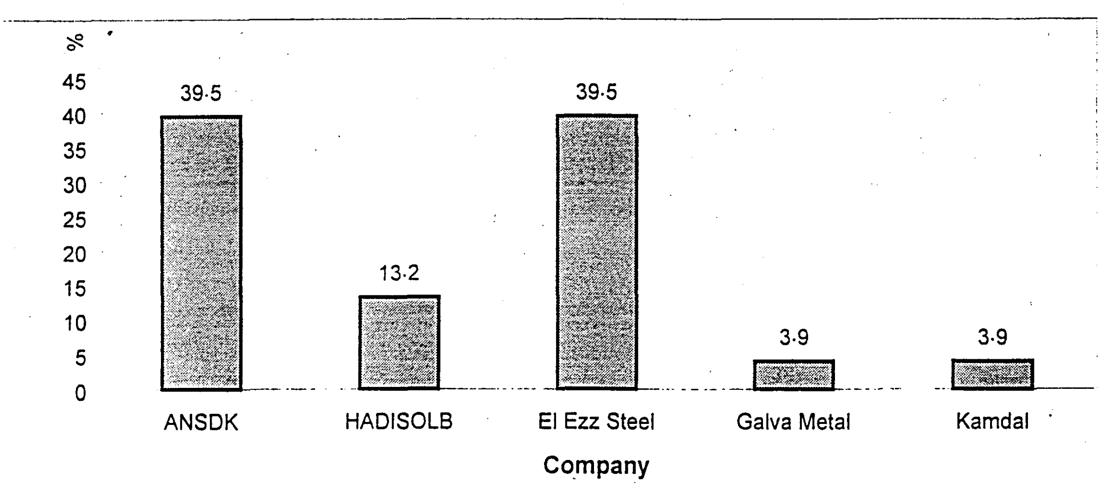

Figure 3.5 Projected Egyptian flat steel market shares in 2001(Buxton 1999)

3.2 Material Flow Diagram of ANSDK Supply Chain

The re-bar industry is part of the construction environment. It produces primarily the direct reduced iron, which uses with scrap and other additives in producing the steel billets (semi finished). The billets are used to produce the final product (rod and bars) which is used in construction industry. Figure 3.7 shows the material flow diagram of ANSDK.

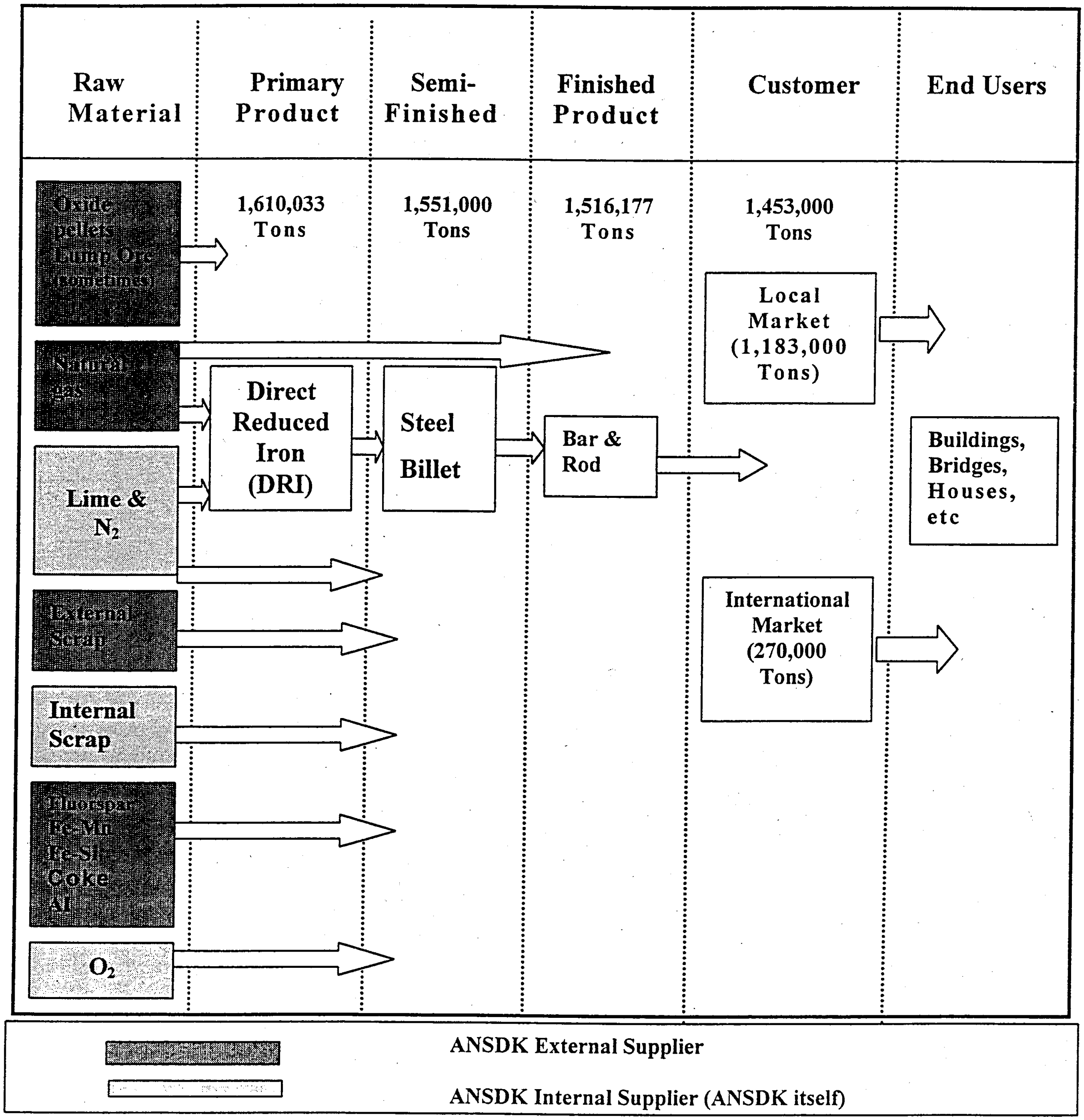

Figure. 3.7 Material flow diagram of ANSDK supply chain

3.3 Information Flow Model of Supply Chain of ANSDK

Every company has its own information model, which it may be different from system to system according to its philosophy and needing. Figure 3.8 shows the ANSDK information model.

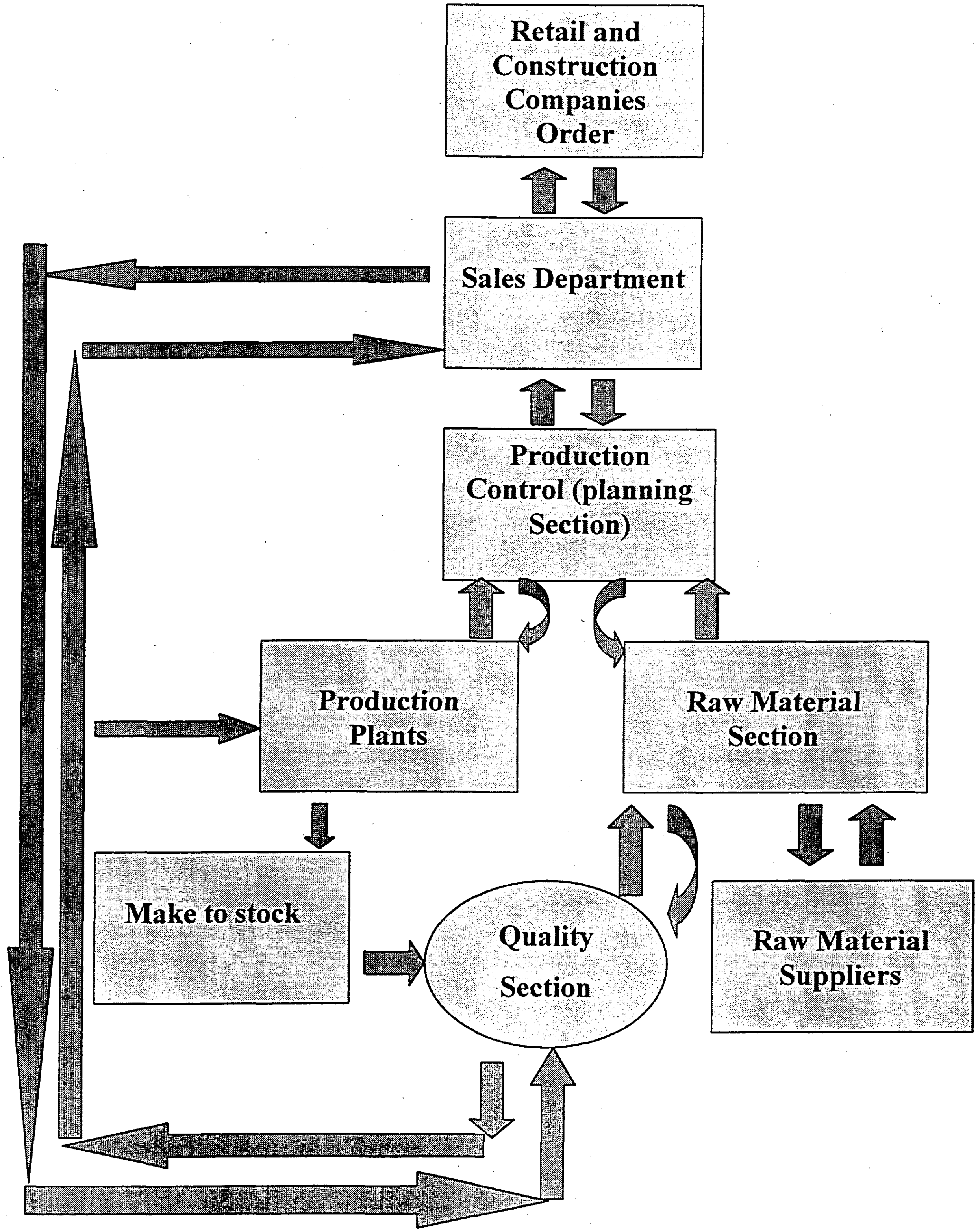

Figure 3.8 Information flow model of supply chain of ANSDK

The information flow chart shows how the steel plant places an order for their customers; rely on its own production program. 60% of customers work most of the time without stock that is why most of the order should be placed for immediate delivery. On the other hand 40% of customers can places orders in advance depending on construction programs. When orders are placed, the production plan is prepared, indicating the required materials and supplies to achieve this order. The most important operating policy of the company is to cover 100% of the demand. That is why the company maintains the maximum level of stock, in other word, the company produces to stock (75000 tons/month Bars and 65,000 tons/month Rod). But over production may affect the operating performance, quality and cost.

3.4 Input-Output Analysis of ANSDK

In conjunction with material and information flow analysis, input-output analysis (IOA) can provide useful information to understand any improvement opportunity through understanding the context in which operation is set (Slack 1999). IOA takes into account of laid down operating procedures, functional definitions, field data, activity sampling, and job description. With the aid of IOA those flows of information relevant to the production scheduling system were mapped. Figure 3.9 shows the IO block diagram of ANSDK production scheduling system. The input-output analysis for the materials and supplies orders transports production schedule, and re-bar dispatches. This analysis as any other balance calculation should give information about material volumes, prices, costs and delivery time. The IO diagram of ANSDK clarify the requirements of the internal customers (like production and maintenance departments) who are served by the outputs from the process (like orders for raw materials and consumables, cash flow, Invoices...etc), and clarify the requirements of the process from the suppliers (like Money, raw materials, consumables.. etc)

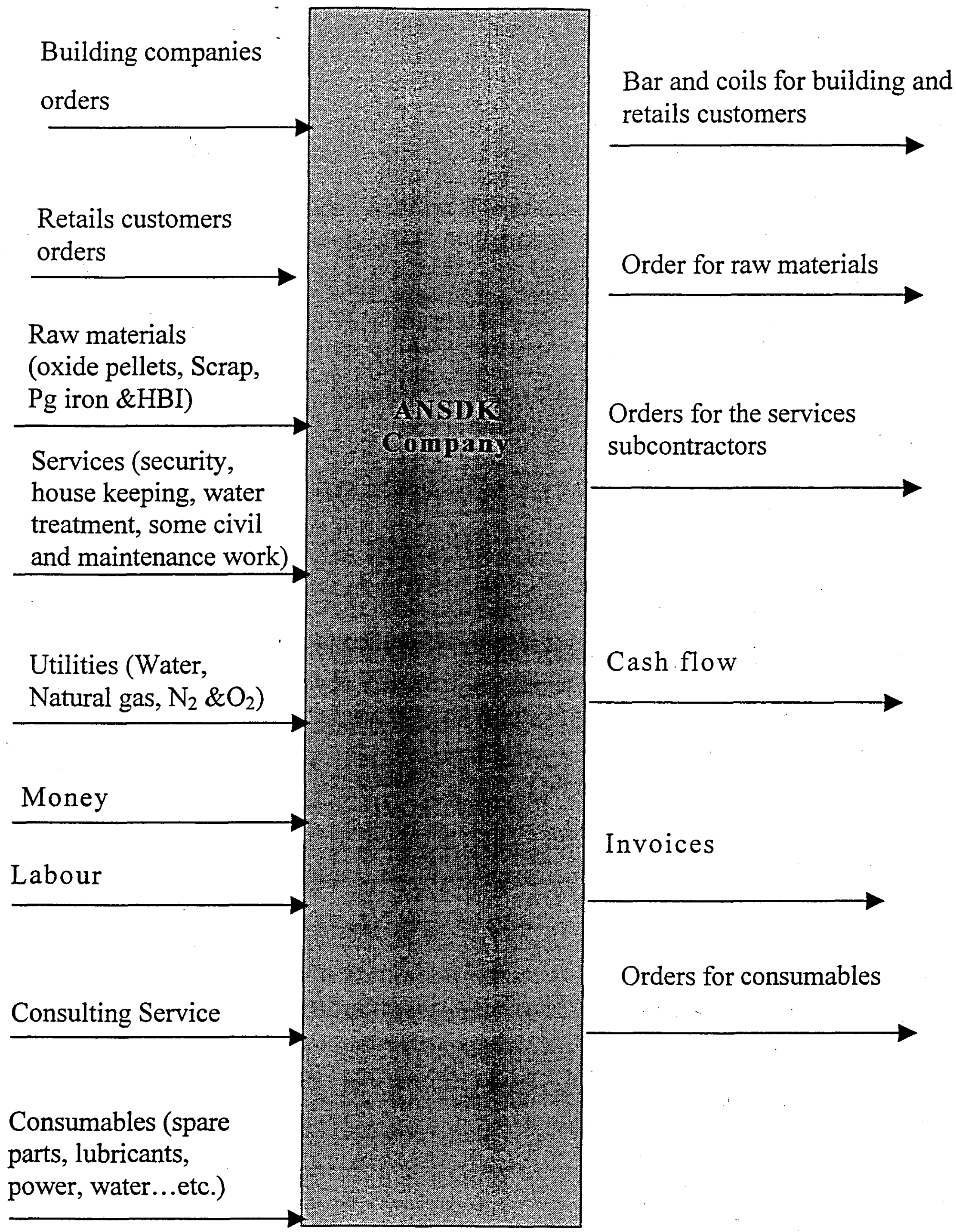

Figure 3.9 Input-Output analysis of the ANSDK Company

3.5 Process Chart of ANSDK

Input-output diagram gives a useful overview of the process context of improvement opportunities, A more detailed technique is the process chart. Process chart gives a detailed understanding of parts of the process where some sort of flow occurs (Slack 1999). Figure 3.10 shows the process chart from raw material section through the ANSDK process till the final products and end-customers. There are 19 processes, 9 transfers, 5 delays, 11 inspections and 6 inventories through all the process to produce either rod or bar steel, total time is 74 and 8hrs from the raw material suppliers till the end customers. The process chart shows two critical areas, first one is inventory, where produced time /inventory time ratio is 0.94. Most of the inventory time (85%) is represented by final product inventory, which may stay for period more than one month depending on the sales rate and market condition. The other area is the delays, where the produced time/delay time ratio is 1.5, 91% from this delay time is due to shipment delay at the supplier of raw material port before loading.

Description	Qty	Time	Activity	Dista--nce	Remarks
Raw Material Section					
1. Send a annual plan to oxide pellets suppliers and shipping company by end of Nov.			O ⇨ D □ Δ		
2. Received confirmation from the supplier and shipping Companies		7 days	O ⇨ D □ Δ		
3. Lay days for loading board		1~15 days	O ⇨ D □ Δ		
4. Loading of Shipment		1~2 days	O ⇨ D □ Δ		
5. Send the material to Egypt		15~20 days	O ⇨ D □ Δ		15 (from Sweden), 20 From Brazil
Mineral Jetty					
6. Check regulations documents like Medical check, Immigration visa...etc.		1.5 hrs	O ⇨ D □ Δ		
7. Preparation for unloading operation (open the oxide rooms, and adjust the crane)		0.5 hr	O ⇨ D □ Δ		
8. Unloading operation	140,000 Ton	4 days	O ⇨ D □ Δ	1 km	By conveyors and gantry
9. Stacking the material in stacking yard according to stacking plan (for smooth feeding to DRP1 and DRP2)		within the unloading 4 days	O ⇨ D □ Δ		

10. Reclaiming (feed the materials to plants (DRP1 and DRP2) oxide Bins	depend on DRP demand	11 min to DRP1 18 min to DRP2	○ ⇨ D □ △	1.7 Km 2.7 Km	

2 Direct Reduction Plants

11. Material is stored in 3 different bins in DRP1 and DRP2			○ ⇨ D □ △		
12. Charge the oxide pellets to the two furnaces by furnace feed conveyors.	150 ton	1.0 hr	○ ⇨ D □ △	40 m	

13. Reduced the iron oxide to reduced iron by using reduced gases (CO+H2)	100~130 ton	1.0 hr	○ ⇨ D □ △		Continuos process
4. Take two samples each 4 hrs from each furnace and send them to laboratory	20 kg/sample	10 mins	○ ⇨ D □ △		
15. Transfer the reduced iron to the three DRI silos where inert gas is injected to keep quality.	100~130 ton	1.0 hr	○ ⇨ D □ △	116 m 220 m	From DRP1 From DRP2
16. Keep the DRI in silos for 3 days			○ ⇨ D □ △		
17. Transfer the DRI from silos to SMP bunker Or to stock yard through the truck bin	200~350 ton	1.0 hr	○ ⇨ D □ △	109~144 m 56 m	109m from DRP1 & 144m from DRP2

Steel Making Plant (4 EAF)

18. Charge the Electric Arc furnace by A. DRI by conveyors from SMP bunkers B. Scrap+DRI+Coke (scrap bucket) C. Ferro alloys	 60 tons 30 tons	 11 mins	○ ⇨ D □ △		Continuos feeding during melting according to steel grade
19. Melting process:- A. On to Melt down (from power on to complete down) B. Melt down to tap to the ladel (tapping) C. Power off and recharge the scrap bucket	 80 tons 80 tons	 66 mins 8 mins 11 mins	○ ⇨ D □ △		
20. Send sample to laboratory for analysis			○ ⇨ D □ △		
21. Tapping to ladel			○ ⇨ D □ △		
22. Treatment the molten steel on ladle furnace		30 mins	○ ⇨ D □ △		
23. Transfer to C.C and stay in queue for casting		30~50 mins	○ ⇨ D □ △		

Continuos Casting (3 machine)

24. Preparation of continuous casting machine to casting		40 mins	○ ⇨ D □ △		
25. Receiving ladel filled with molten steel with specified grade according to daily work order and start casting	80 tons	30 mins	○ ⇨ D □ △	40 or 60 m	according to which machine will be used for casting every 10, 30 and
26. Chemical analysis	2-3 times	60 mins	○ ⇨ D □ △		45 mins if needed
27. Casting, cutting the billet to the required length	80 tons	60 mins	○ ⇨ D □ △		
28. Inspection, identification and marking the billets, and checking billet defects (visually)	80 tons	20 mins	○ ⇨ D □ △		
29. Waiting for quality section decision.			○ ⇨ D □ △		depend on the results of the samples

ROD Mill

30. Stacking the billets according to grade wise	80 tons	30 mins	○ ⇨ D □ △		
31. Checking number of billets, number of heat and marking first billet of new heat by painting	80 tons	30 mins	○ ⇨ D □ △		
32. Adjusting the billets inside reheating furnace according to length automatically and reheating	80 tons	40 mins	○ ⇨ D □ △		
33. Check dimension, Recording the temp. And counting the billets on each strand			○ ⇨ D □ △		every 15 mins
34. start rolling according to charging order, size wise and speed control	80 tons	35 mins	○ ⇨ D □ △		
35. On line sampling to check product dimension surface apparence every 5 billets		during the 35 mins	○ ⇨ D □ △		
36. Cooling the rings by either the air or water according to steel grade & size wise.		during the 35 mins	○ ⇨ D □ △		
37. Trimming on stelmore conveyor to remove un-cooled rings and adjust the top rings at coil reforming station for both strands.		during the 35 mins	○ ⇨ D □ △		
38. 3 samples from heat are sending to lab. for analysis the dimension and mechanical testing.		during the 35 mins	○ ⇨ D □ △		
39. Compact and tie the coils.	80 tons	40 mins	○ ⇨ D □ △		
40. Weighing on rod mill scale and labelling by stamping.	80 tons	30 mins	○ ⇨ D □ △		

41. Shipping for stacking indoor waiting for mech. And dimension test results.	80 tons	32~48 hrs	O ⇨ D □ Δ		
42. Shipping and stacking size wise in dispatching yard. (final product inventory)	50,000 tons	One month	O ⇨ D □ Δ		

2Bar Mill Units

43. Stacking the billets according to grade wise	80 tons	30 mins	O ⇨ D □ Δ		
44. Checking number of billets, number of heat and marking first billet of new heat by painting	80 tons	30 mins	O ⇨ D □ Δ		
45. Adjusting the billets inside rehearing furnace automatically			O ⇨ D □ Δ		
46. Reheating the billets and discharge the billets from the furnace.	80 tons	40 mins	O ⇨ D □ Δ		
47. start rolling according to charging order, size wise and speed control	80 tons	35 mins	O ⇨ D □ Δ		
48. Check product dimension & gap adjustment		within the 35 mins	O ⇨ D □ Δ		
49. Billet top & tail cutting to avoid any irregularity or defect in billet terminals		within the 35 mins	O ⇨ D □ Δ		
50. On line ambling for product dimension surface and unit weight control and recording every 10 billets by vernier and sensitive scale		within the 35 mins	O ⇨ D □ Δ		
51. 3 samples from heat are sending to lab. for analysis the dimension and mechanical testing.		within the 35 mins	O ⇨ D □ Δ		
52. Product length check & control by shear gauge or fixed stoppers with metering and surface check.			O ⇨ D □ Δ		
53. Bundling (batching, compacting & tying)			O ⇨ D □ Δ		
54. Weighing on bar mill scale & recording by serial number			O ⇨ D □ Δ		
55. Shipping for stacking indoor waiting for mechanical and dimension test result.	32-48 hrs		O ⇨ D □ Δ		
56. Shipping and stacking size wise in dispatching yard (final prod. Inv.)	one month	75,000 tonds	O ⇨ D □ Δ		

Sales Department

57. Schedule for market survey is proposed including personnel who will participate in survey, territories, Company distribution channel and importers who will visited.		By the 2nd week of Each month.	O ⇨ D □ Δ		
58. The market survey is conducted and report finalized including:- * level of demand, level of supply, & level of market stock. * Prevailing selling prices		3rd and 4th week	O ⇨ D □ Δ		
59. Announcing price list			O ⇨ D □ Δ		
60. Issuing purchasing request to the customer		10 mins	O ⇨ D □ Δ		
61. Contract signature with the customer.		10 mins	O ⇨ D □ Δ		
62. Inform the shipping section that the customer sign the contract and pay the money (cash or by cheques)		10 mins	O ⇨ D □ Δ		
63. Transfer the products from the company stock yard to the customers side	5000 t	day	O ⇨ D □ Δ		depend on the customers request and market conditions

Total processes (to produce either rod or bar)	19 O
Total transfers (to produce either rod or bar)	9 ⇨
Total delays (to produce either rod or bars)	5 D
Total inspections (to produce either rod or bar)	11 □
Total inventories (to produce either rod or bar)	6 Δ

Figure 3.10 Process chart of ANSDK

3.6 ANSDK Inventory.

Figures 3.11 to 3.14 show the inventory assets, for raw materials, primary and semi products, finished product, and spare parts inventories, since 1986 (start up). It is clear from those Figures how deep of inventory management problem at ANSDK.

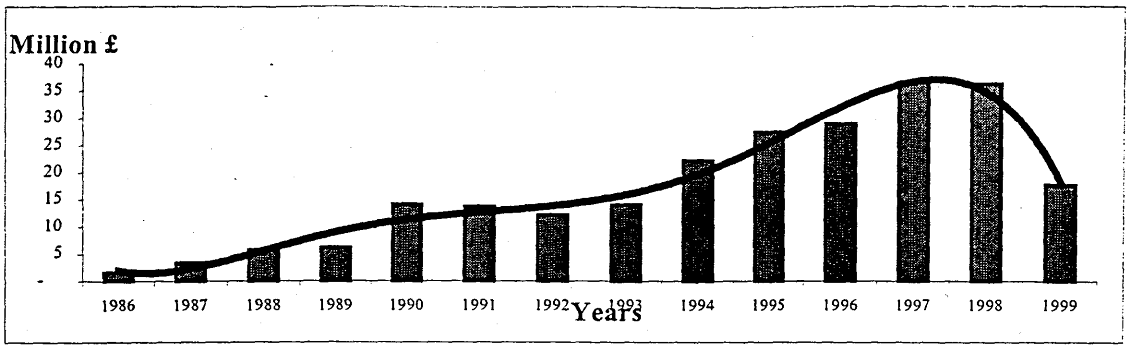

Figure 3.11 Major and Aux. Raw Material inventory assets

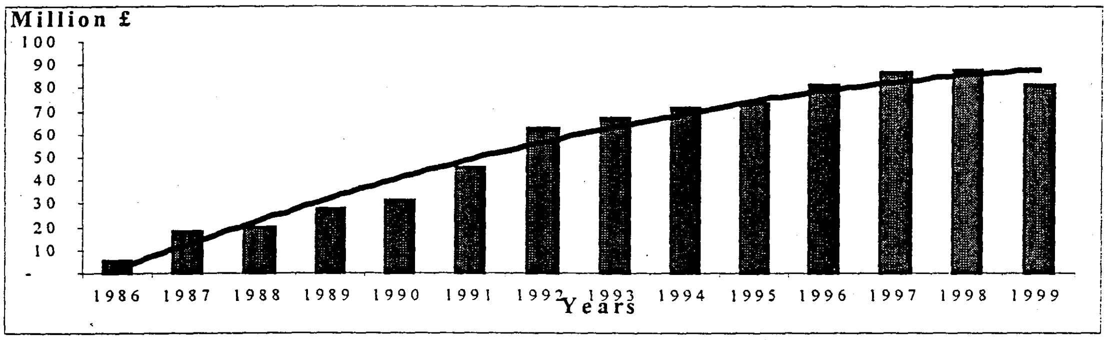

Figure 3.12 Spare parts and consumables assets

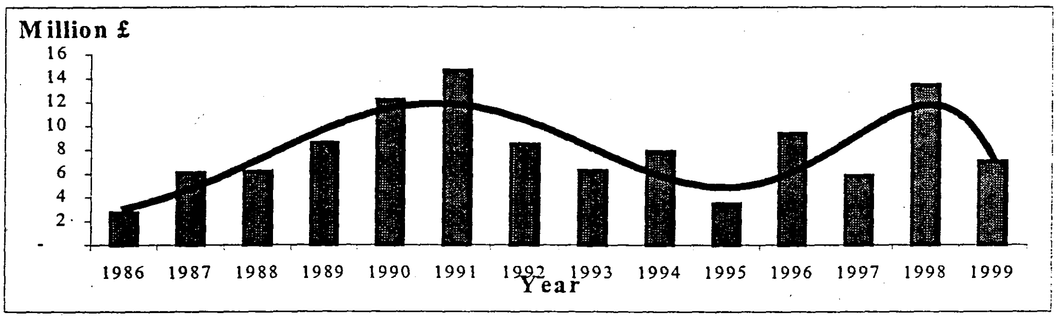

Figure 3.13 Finished product inventory asset

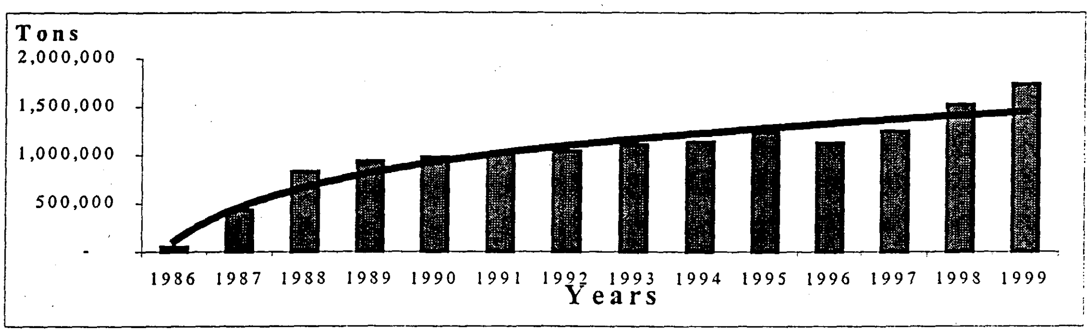

Figure 3.14 Production volume

The inventory assets of raw materials and spare parts (Figures 3.11 and 3.12) increased yearly but in 1999 both of them were decreased, where raw material stock decreased by 50% and spare parts stock by 7% in spite of increasing production volume by 14%. Both raw materials and spare parts stocks reached £99 million, where the spare parts stock reached to £81million and raw materials stock reached to £18million. At the same time the net profit was decreased from £24.7millionon 1997 to £4.9million on 1999 (80%) (See table 3.1). Inventories of raw materials and spare parts are 20 times more than the net profit in 1999 and half of the total turn over in the same year. On the other hand the semi-finished and finished product inventories (Figures 3.24 and 3.25) fluctuated depending mainly on the steel market. The inventory of final product jumped by 300% in 1999 comparing with 1998, because of high price of ANSDK products (£200/ton) comparing the other Egyptian competitors who imported the billets from Eastern Europe with cheap price (£96/ton), consequently produced re-bars with lower price (£160/ton).

Spare parts inventory represents a big problem to ANSDK, where it costs ANSDK £81million (16 times more than the 1999 net profit and 35% turn over of the same year, in a time the company try to reduce its expenses and product price to survive in a highly fluctuated market.

3.6.1 Spare parts inventory

The main customers for spare parts in ANSDK are Maintenance and Utilities Department (MUD) and production department (PRD). Figures 3.16 and 3.17 respectively show the comparison between the budget plan for purchasing, actual purchasing and actual consumption of spare parts in ANSDK since 1994. The Figures 3.27 and 3.28 show the actual consumption of spar parts is less than the actual purchasing which causes accumulation of non-used spar parts yearly.

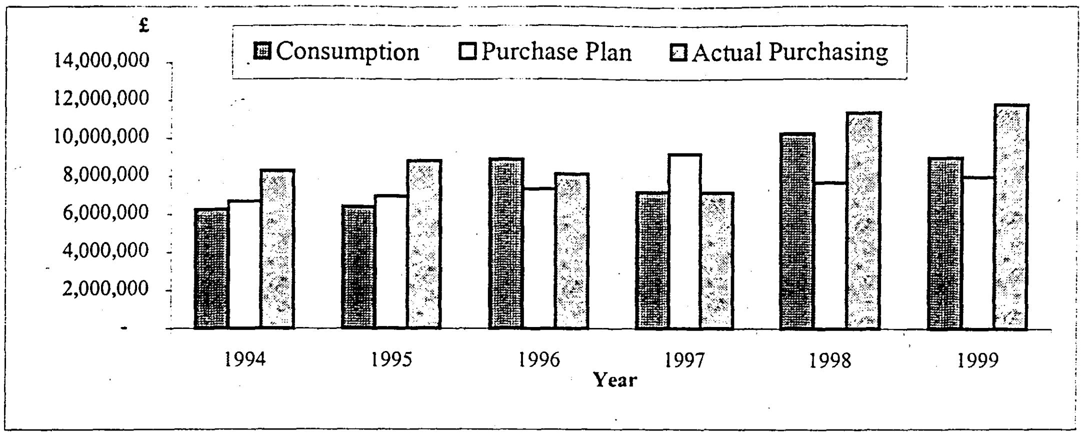

Figure 3.16 Comparison for the purchase plan, , actual purchasing and actual consumption of spare parts for MUD since 1994

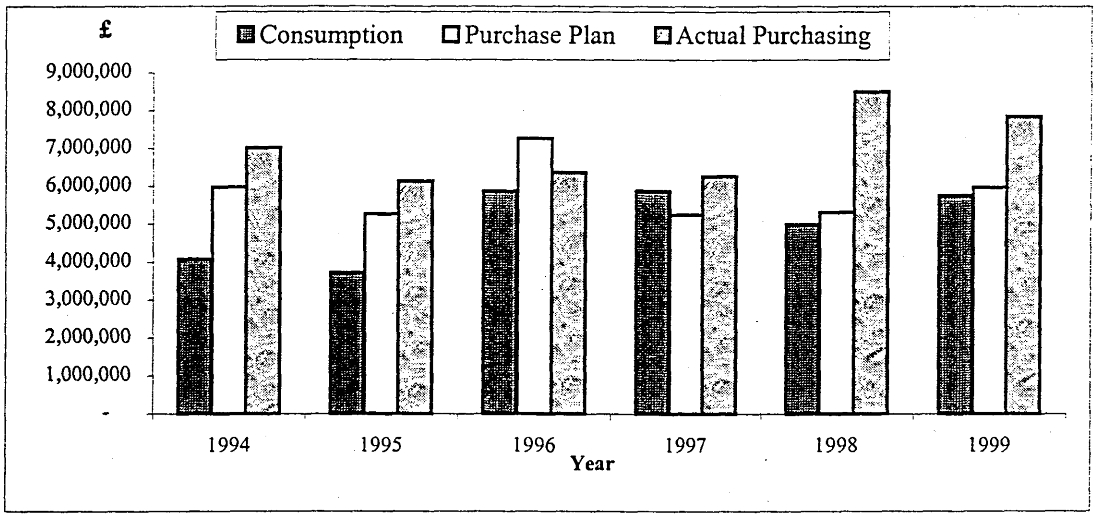

Figure 3.17 Comparison for the purchase plan, , actual purchasing and actual consumption of spare parts for MUD since 1994

The main target for production and maintenance departments is to achieve the highest pant availability to achieve high production volume. For this target, they bought huge amount of spare parts to avoid any stoppage for production lines, From this understanding leads to accumulated stagnated items (non-used spare parts) because of changing the technology or because it became old fashion .Now the stagnated spare parts stock worth more than £29 million as shown in Figure 3.18.

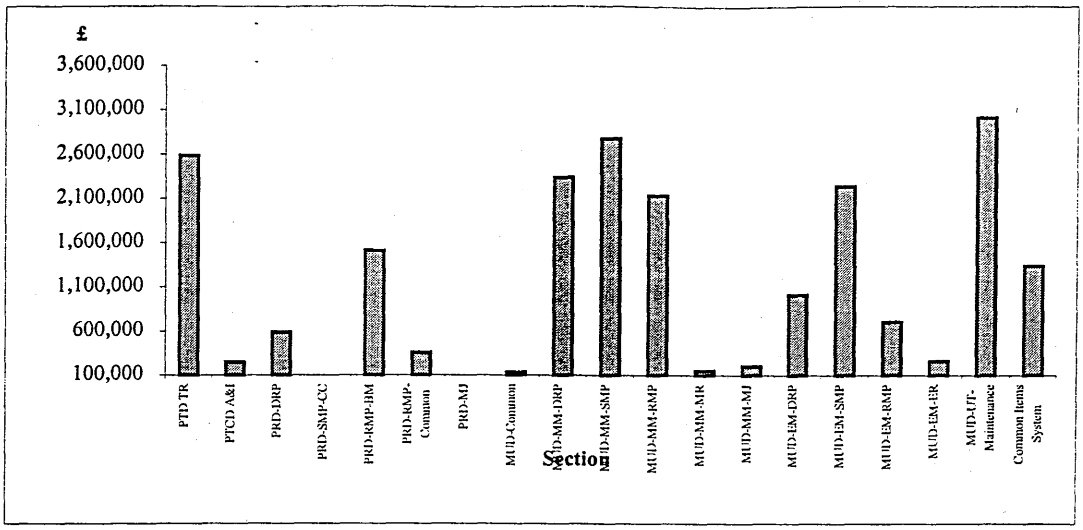

Figure 3.18 Value of stagnated spare parts for ANSDK sections

3.7 ANSDK Value Add

Figure 3.19 show the value added of processing the raw material to produce one ton re-bar or rod at ANSDK, where we can noticed that the highest value added is due to converting the Direct Reduction Iron to molten steel in Electric arc furnaces.

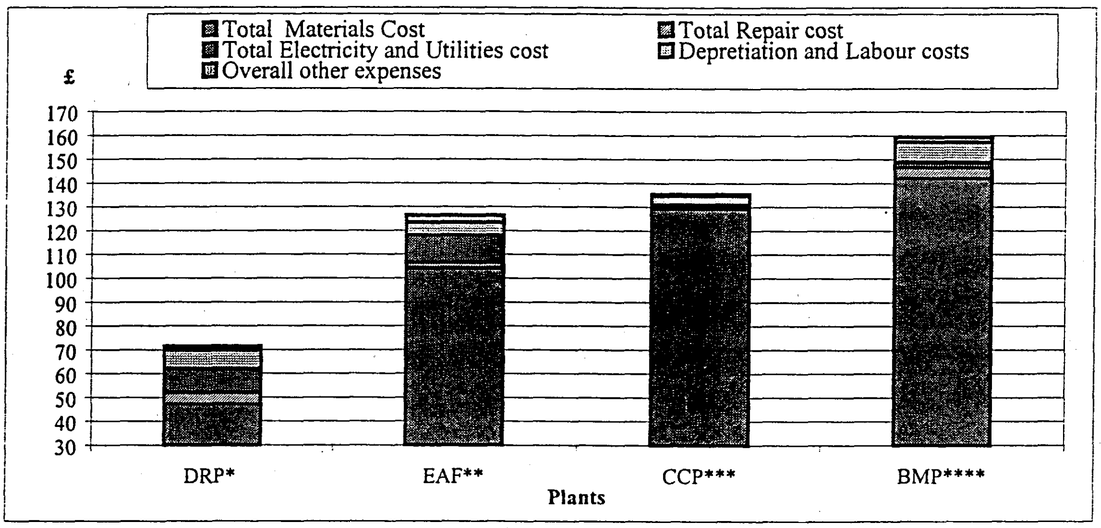

Figure 3.19 Overall value added of ANSDK for each plant
* Direct Reduction Plant ** Electric Arc Furnace *** Continues Casting Plant
**** Bar Mill Plant ***** Rod Mill Plant

Figure 3.20 shows the percentages of value add to produce one ton re-bar through the production plants in ANSDK. This figure shows that DRP and SMP represented 90% of total value add, the following figures will show the details and reasons for this high share of DRP and SMP.

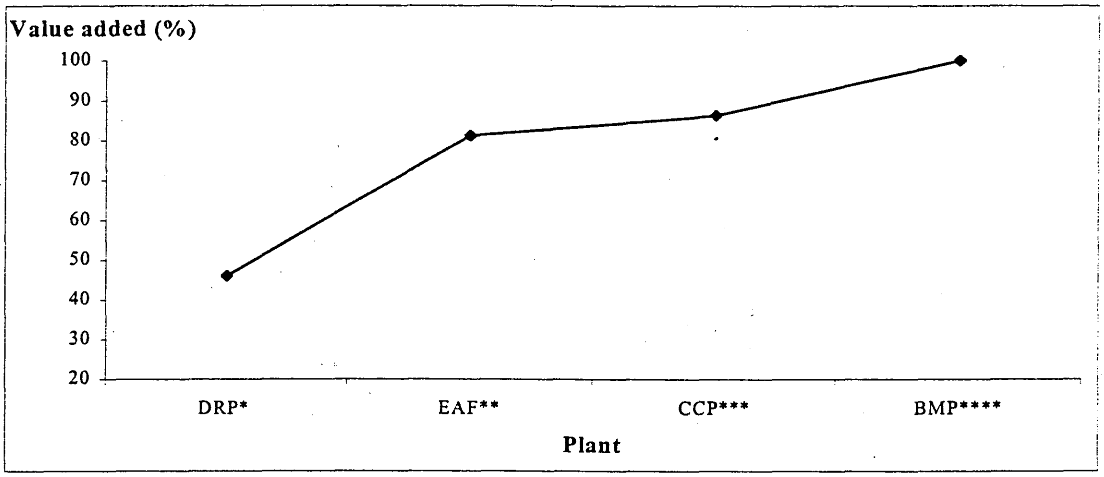

Figure 3.20 Overall percentage value added at different production sections of ANSDK

Figures 3.21and 22 show that the highest material cost is concentrated in Direct reduction and steel making plants, where they consume around 80% of total material cost at ANSDK.

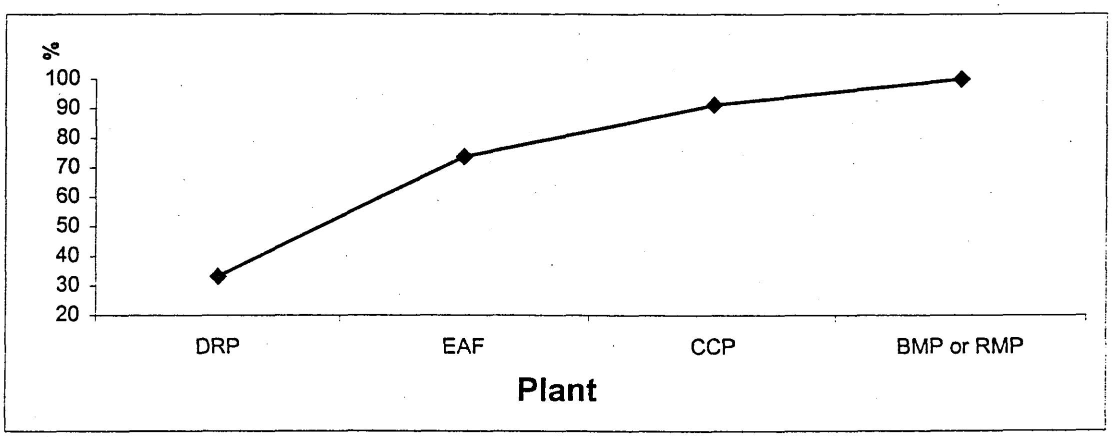

Figure 3.21 Percentage of materials cost to produce one ton re-bar in ANSDK

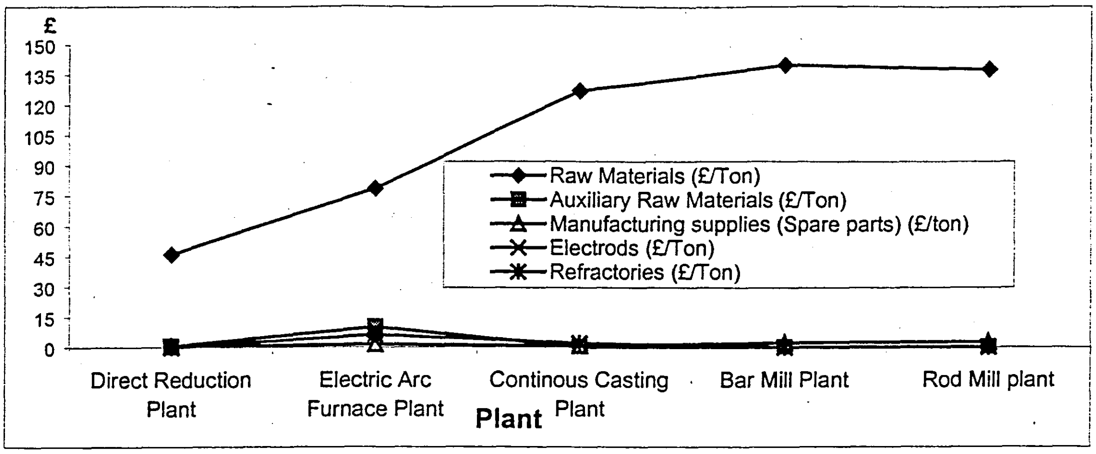

Figure 3.22 Individual raw material cost to produce one ton re-bar

Figure 3.23 to 3.26 show that both direct reduction and bar mill plants have the highest repair and depreciation costs where DRP represents 39% from overall repair cost and 34% from the overall depreciation cost. On the other hand BMP represents 30% from the overall repair cost and 40% from overall depreciation cost. Figures 3-27 and 3.28 show that both of DRP and EAF represent ~90% of total electricity and utilities consumption. Where the DRP consumes huge amount of N.G (56kNCM/hr/2 plants) and SMP consumes 798 kWH electricity. Figures 3.29 and 30 show the other costs like transportation, laboratories, and direct department overhead.

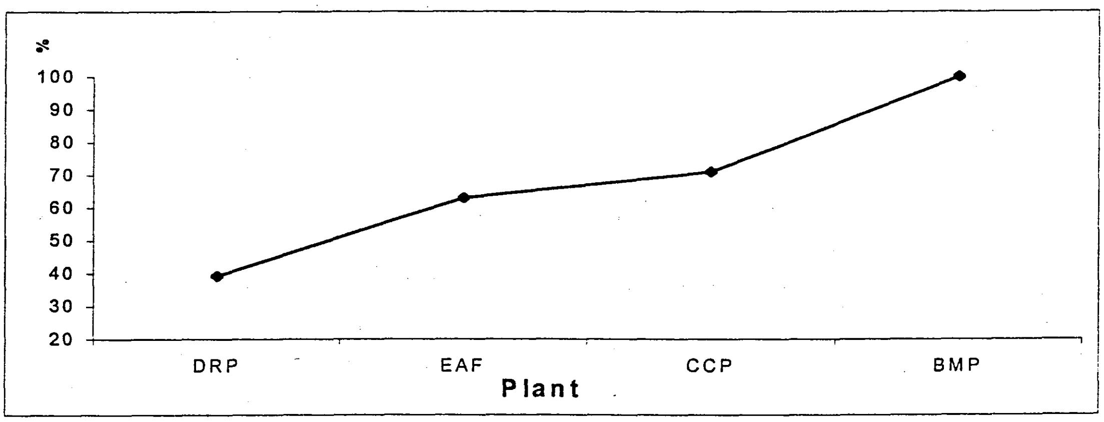

Figure 3.23 Average percentage repair cost for each plant

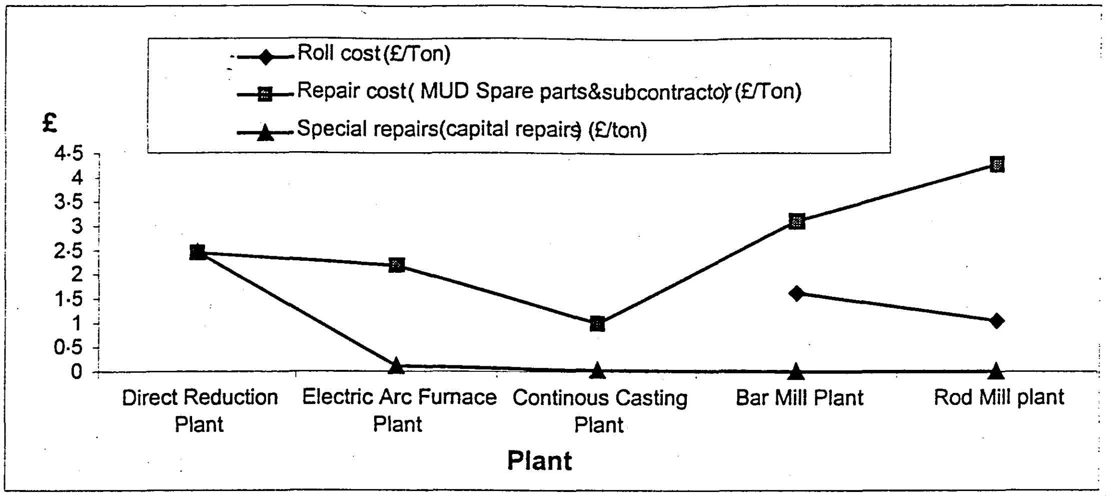

Figure 3.24 Detail of the repair cost

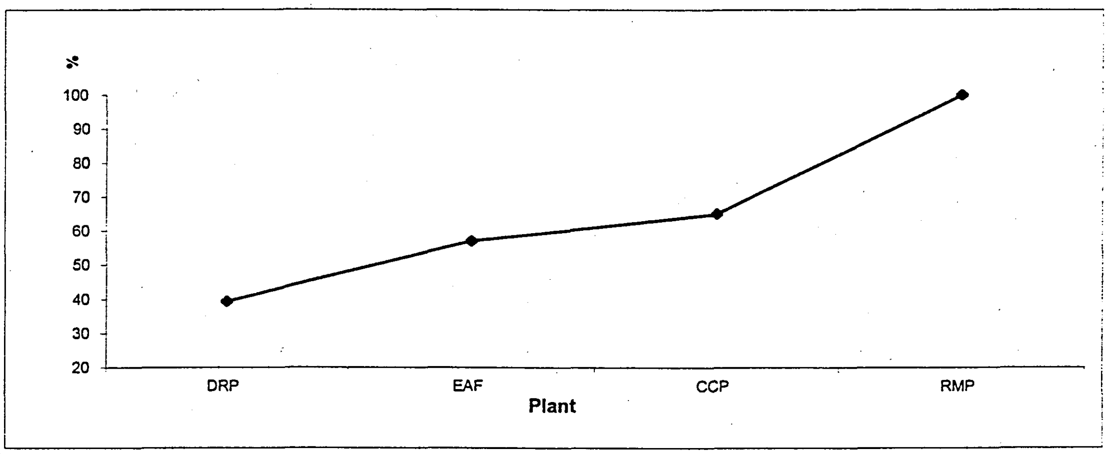

Figure 3.25 Depreciation and labour cost

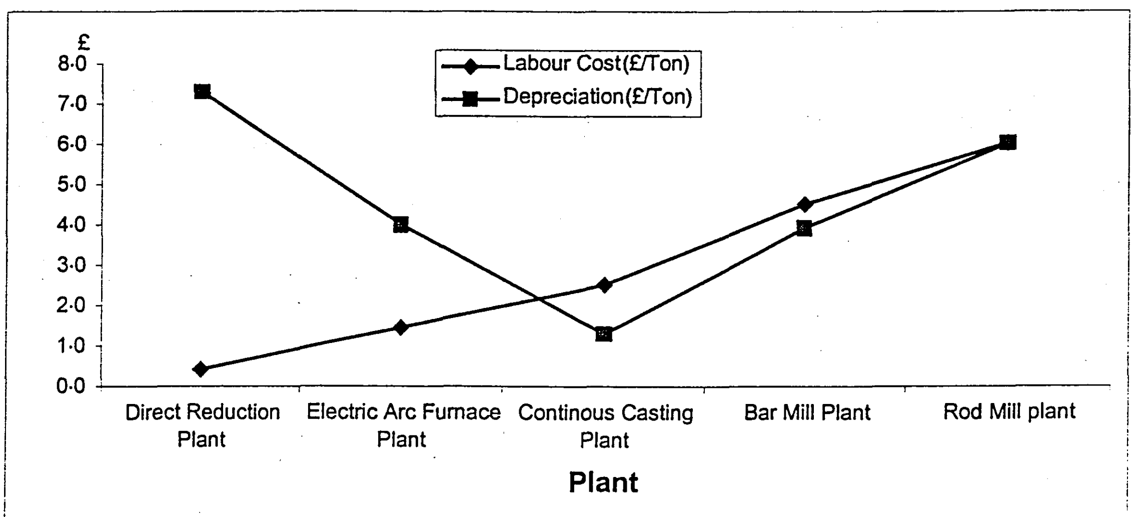

Figure 3.26 Labour and depreciation cost for each plant

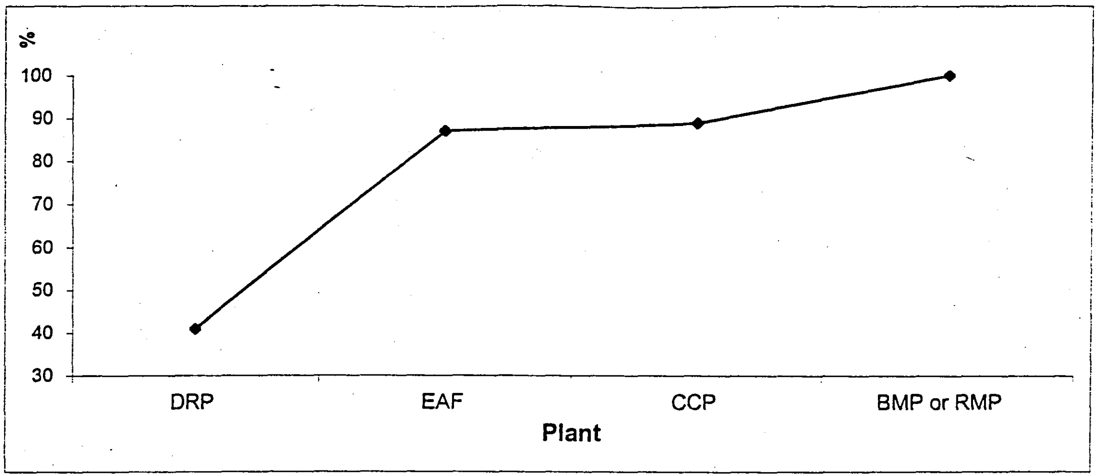

Figure 3.27 Overall percentage Electricity and Utilities consumption for each plant

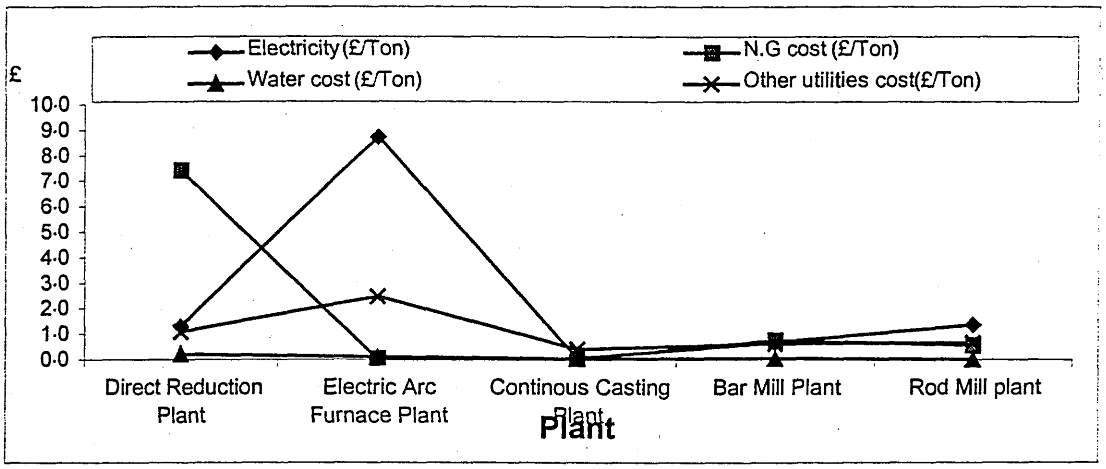

Figure 3.28 Individual electricity and utilities

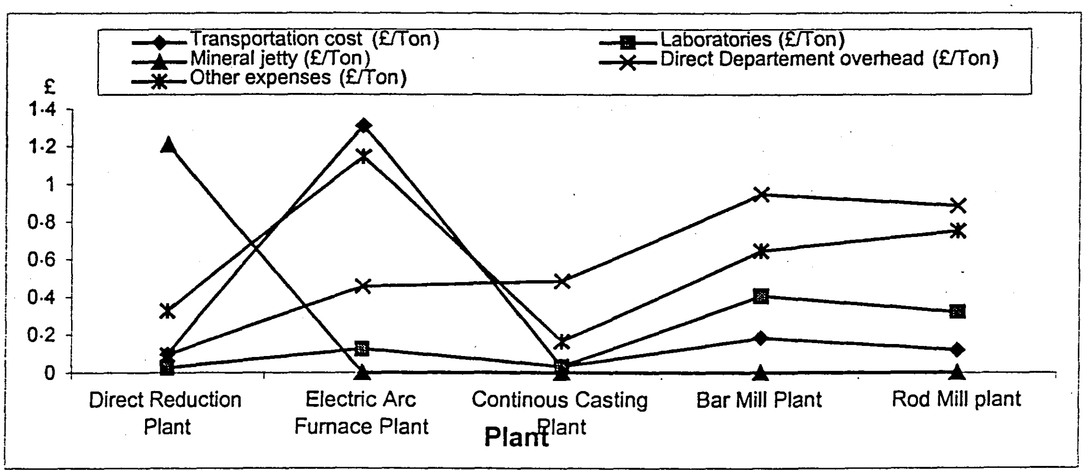

Figure3.29 Individual costs of other expanses

Item	Direct Reduction Sec.	Electric Arc Furnace Sec.	Continuos Casting Sec.	Bar Mill Sec	Rod Mill Sec.
Raw Materials (£/Ton)	46.0	78.6	127.7	139.7	136.8
Auxiliary Raw Materials (£/Ton)	0.5	10.1	0.0	0.0	0.0
Manufacturing supplies (Spare parts) (£/ton)	0.5	1.4	0.6	2.2	2.5
Electrodes (£/Ton)		8.1		0.0	0.0
Refractory (£/Ton)	0.0	6.2	1.9	0.0	0.0
Total Materials Cost	*47.1*	*104.4*	*130.1*	*141.9*	*139.3*
Roll cost (£/Ton)				1.6	1.0
Repair cost (MUD Spare parts & subcontractor) (£/Ton)	2.4	2.2	1	3.1	4.3
Special repairs (capital repairs) (£/ton)	2.5	0.1	0.03	0	0
Total Repair cost	*4.9*	*2.3*	*1.03*	*4.7*	*5.3*
Labour Cost (£/Ton)	**0.4**	**1.4**	**1.1**	**2.0**	**1.5**
Electricity (£/Ton)	**1.3**	**8.7**	**0.0**	**0.7**	**1.4**
Depreciation (£/Ton)	**7.3**	**4.0**	**1.3**	**3.9**	**6.0**
N.G cost (£/Ton)	7.4	0.0	0.0	0.7	0.6
Water cost (£/Ton)	0.2	0.1	0.0	0.0	0.0
Other utilities cost (£/Ton)	1.1	2.5	0.4	0.6	0.7
Overall utilities cost (£/Ton)	*8.7*	*2.6*	*0.5*	*1.4*	*1.2*
Transportation cost (£/Ton)	0.1	1.3	0.0	0.2	0.1
Laboratories (£/Ton)	0.0	0.1	0.0	0.4	0.3
Mineral jetty (£/Ton)	1.2	0.0	0.0	0.0	0.0
Direct Departement overhead (£/Ton)	0.1	0.5	0.5	0.9	0.9
Other expenses (£/Ton)	0.3	1.1	0.2	0.6	0.8
Overall other expenses (£/Ton)	*1.8*	*3.0*	*0.7*	*2.2*	*2.1*
Total cost to produce one ton/Section (£/Ton)	*71.4*	*126.4*	*134.7*	*156.8*	*156.8*

Table 3.2 Spreadsheet model of ANSDK according to 1999 results

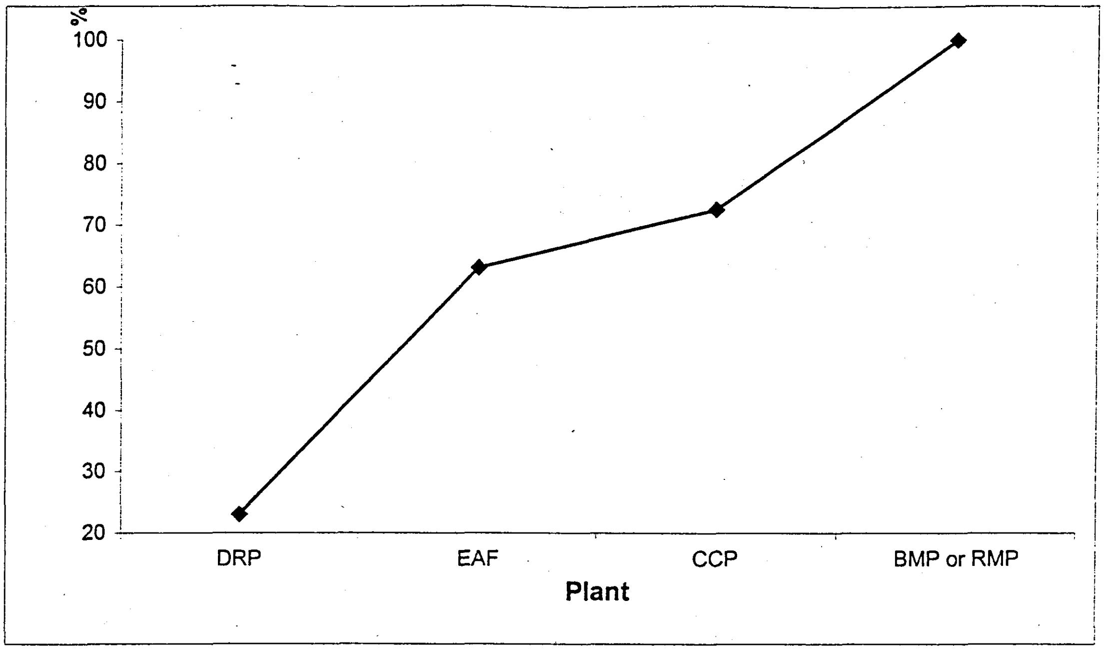

Figure 3.30 Average percentage cost for other expenses

From the Figures 3.20 to 3.30, it is clear that the DRP and SMP sections represented 85% of the total industrial cost to produce one ton re-bar or rod. Actually DRP contributes 43% and SMP 42% from the total cost. That makes the two sections are the main target for any cost reduction at ANSDK.

3.8 Spread Sheet Model of ANSDK

Table 3.2 gives a detail spread sheet model for requirements, raw materials, repair cost, utilities and electricity cost, labour and depreciation cost, and overall other expenses to produce one ton re-bar. This model is very useful to show effect of changing any of individual cost to measure the product cost. For example changes in the cost of natural Gas, Electricity and Labour are viewed in the range ± 25%. Figure 3.31 show that the final product cost affected is more by Electricity and Natural gas costs rather than Labour costs. For example the final product (ton re-bar) increases by £2.8/ton re-bar in case of increasing electricity cost .by 25%. On the other hand it will increase only by £1.7/ton, in case of increasing labour cost by 25%.

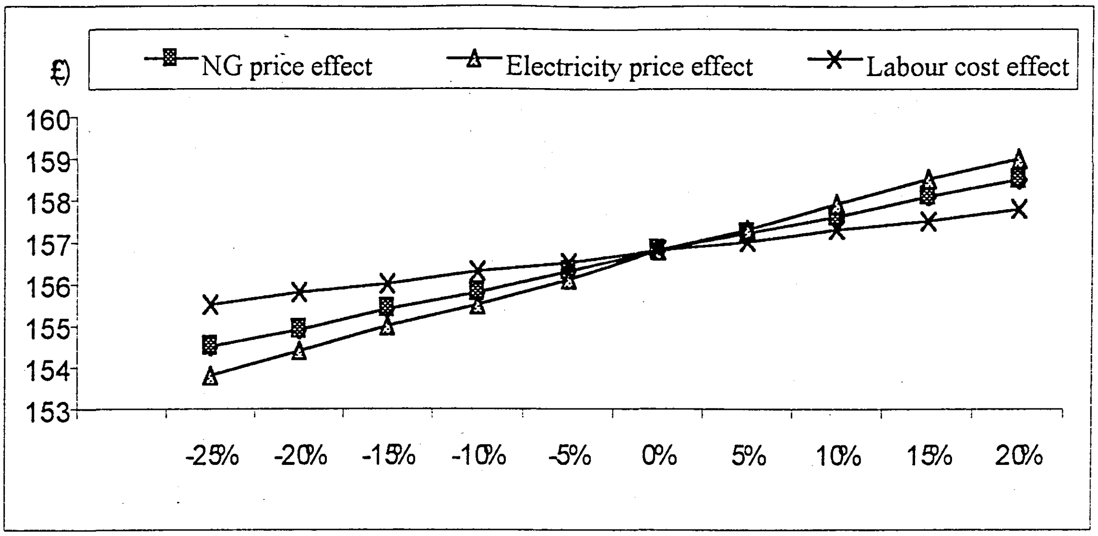

Figure 3.31 Relation between N.G, Electricity and labour cost increase and final product cost

4. CONCLUSION

Steel market is becoming more and more unstable and fluctuated. The competition is very hard especially from the old Soviet Union countries and China. So to survive in this kind of market ANSK should improve quality and reduce cost. Supply chain management presents one way to achieve this target. In this project we could be analyzed and evaluated the overall supply chain of steel company (ANSDK) to see where are the critical factors, which could to improve the company performance.

This research program employs the system dynamics frame work developed by Hafeez *et al.* (1996). The framework consists of two overlapping phases. Phase I include the analysis of relevant information in a structured format and construction of conceptual model. Phase II involve the transformation of the conceptual model into a quantitative model and conducting extensive dynamic simulations and testing what-if scenarios. The methodology has been successfully applied to analyze many major supply chain structures including IBM, Lucas and Allied Steel and wire. Using the methodology system analysis of ANSDK was carried out using input-output analysis, information flow diagram, process flow diagram, material flow diagram and plotting a range of inventories and production data. spread sheet model was built to see how the cost of different items, like raw materials, natural gas, electricity, labour..etc. affect the final product cost and consequently the sales price. This model enables

ANSDK to predict what will be the effect on the final product cost in case of changing any of the manufacturing cost items.

The analysis reveals that inventories control (raw materials, final product and spare parts) causes a big problem for (ANSDK), where the inventory assets of raw materials and spare parts represents £128 million. Spare parts inventory asset itself reached £90 million and raw materials stock reached £38million. At time the net profit was decreased from £24.7millionon 1997 to £14.5million on 1998 (41.3%) (See table 3.1). Inventories of raw materials and spare parts are 5.2 times more than the net profit in 1997 and also represent 50% from total turn over of the same year. Spare parts inventory alone causes a big problem to ANSDK, where it costs ANSDK £90million(3.6 times more than the 1997 net profit and 35% from the turn over of the same year, at a time the company try to reduce its expenses and prices to be survive in a highly fluctuated market. Therefore it becomes increasingly important to study and analyse the spare parts inventory system to modify and reduce its cost. A mathematical model to answer the questions of how much to be ordered and when should it be ordered may provide a very useful scenarios planning tool for the company.

5. MPhil CONTRIBUTION

1. Reviewing supply chain modeling methodology, especially the spare parts inventory control in steel company.
2. A case study company (ANSDK) was analyzed using a number of system dynamics techniques such as system input-output analysis, flow charting, , and material & information flow analysis.
3. Analyzing the inventory data for ANSDK specifically the spare parts inventory.
4. Establishing value-add and non value-add analysis for the ANSDK by taking into account relevant labour, machining and energy consumption costs.

6. Ph.D WORK

Phase II (Ph.D. work) of the project focuses into the following objectives:

- To develop conceptual and analytical models for inventory control strategies
- To confirm the validity of proposed models via statistical/computer simulation analysis.
- To suggest the dynamic behaviour of the steel industry spare parts supply chain and re-engineering strategies (e.g. how to move more rapidly towards a Minimum Reasonable Inventory (MRI) scenario in the presence of capacity constraints, breakdowns and material supply lead-time bottlenecks).

The time scale for the next 24 months is illustrated in Appendix 4.

6.1 Conceptual Model

Using the collection data, (kind of data which could be collected for the ANSDK inventory is shown in Appendix 5) a conceptual model would be constructed to serve as qualitative tool for spare parts supply chain. The conceptual model is to provide a cause and effect relationship in decision making

6.2 Computer Simulation Model

The conceptual model would be translated into a block diagram format. The computer model will be verified by showing it to relevant people in the company and then validated by conducting case study

6.3 Simulating Alternative Spare Parts Inventory Control Strategies

An extensive computer simulation exercise would be conducted to test the appropriateness of various inventory control strategies in a supply chain scenario. The aim is to provide quantitative evidence of the benefit of using a range of inventory control strategies. Company structure would be examined to establish appropriate communication, co-ordination and control framework for implementing optimum inventory control in the supply chain. Appropriate implementation model would be presented.

7. Ph.D. CONTRIBUTION

By using the collection data, conceptual model would be constructed to serve as qualitative tool for spare parts supply chain, to provide a cause and effect relationship in decision making. Then this conceptual model could be translated into block diagram format. The computer model will be verified by showing it to relevant people in the company and then validated by conducting case study. An extensive computer simulation exercise would be conducted to test the appropriateness of various inventory control strategies in a supply chain scenario.

Company structure would be examined to establish appropriate communication, co-ordination and control framework for implementing optimum inventory control in supply chain.

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