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A TOC based Manufacturing System for Robor Tube

by

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1. Introduction

1. INTRODUCTION

1.1 COMPANY BACKGROUND

Robor Tube is the leading manufacturer and distributor of steel tube in pipe in South Africa. The company trades both locally and internationally. It is a division of Robor Industrial (Pty) Ltd, which is a wholly owned division of Barlows Ltd. Barlows Ltd. is a South African based international industrial conglomerate. Robor Tube produces tube and pipe from carbon steel, largely sourced from Iscor, South Africa's main steel producer.

Up until 1994 (the date of the first fully democratic election), South Africa was a largely closed loop economy typified by trade barriers, sanctions and high import duties. The demand for tube and pipe in South Africa was small in world terms, and customers themselves were relatively undemanding. The isolation brought about by the sanctions, has enabled companies to survive without having to pay much attention to strategy or keeping up with global industry trends.

The isolation as well as a lack of demanding customers has led to the situation where Robor Tube and other companies could survive by supplying undifferentiated, unsophisticated commodity products. Very little value has been added in terms of customer needs and requirements. Previous tariff protection land export incentives did nothing to promote global competitiveness. This, of course, changed with the lifting of sanctions and the signing of GATT. The South African market now became accessible to tube manufacturers out of India and the rest of Southeast Asia. The implication of this was that the competitors in the local market were suddenly confronted by advisories outside of the national borders. Due to the foreign competitors' high level of efficiency and productivity, they could compete with the local manufacturers on equal terms.

The new conditions in the market for steel tube and pipe, caused extensive rivalry within the industry. This situation led to strategies that focussed on lowering cost and hence further reducing the focus on the customer's need and requirements. Robor Tube, a profitable company for many years, was suddenly confronted with extreme financial pressures.

The management of Robor Tube was forced by both shareholders and customers to rethink their strategy and approach to strategy. In 1996, the company started investing heavily in capital equipment to upgrade its ancient manufacturing facilities. This was followed by the construction of a state-of-the-art distribution facility as a drive to improve customer service. The company was extremely weak in terms of their information technology infrastructure, and probably 10 years behind leading organisations. In 1997, an ERP (Enterprise Resource Planner) system (BAAN) was installed with the aim to improve the financial, sales and distribution functions of the company.

Manufacturing at Robor Tube is however still in a poor state. Planning and execution systems are mostly manual exercises that do not offer transparency and integration with the rest of the company's systems. At the beginning of 1999, the board of directors gave permission to proceed with the implementation of a modern manufacturing planning and control system. The aim of the proposed new system was the following:

- To improve the profitability of the company over the short and long term;
- To improve customer service by means of reliable, on time delivery;
- To improve the responsiveness of the company to rapidly changing market conditions.

1.2 OBJECTIVE OF THIS REPORT

The objective of this report is to sketch the transformation process at Robor Tube with the emphasis on manufacturing planning and control. This will be done by a brief description of the business environment, followed by the answering of three fundamental questions relating to manufacturing planning and control, around which the rest of the process will be mapped:

- What to change? - The aim of this question is to pinpoint the core problems relating to manufacturing planning and control. In other words, those problems that once corrected, will have a major impact on the company.
- What to change to? – The aim here is to construct a practical solution and to understand what the effect of the planned change will be.
- How to cause the change? – Understanding the psychological processes involved in changing from the current situation to the future situation, and making it happen.

1.3 APPROACH

The approach throughout this report will be to explore the current literature on the subject at hand and to identify any possible relations to Robor Tube in particular. Many possible solutions exist within the literature, and it is the aim of this report to identify those relevant to Robor Tube.

The report applies to Robor Tube, and theoretical solutions are extensively discussed, using the company as a reference. All discussions lead to a solution derived from the discussed theory.

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2. The Business Environment

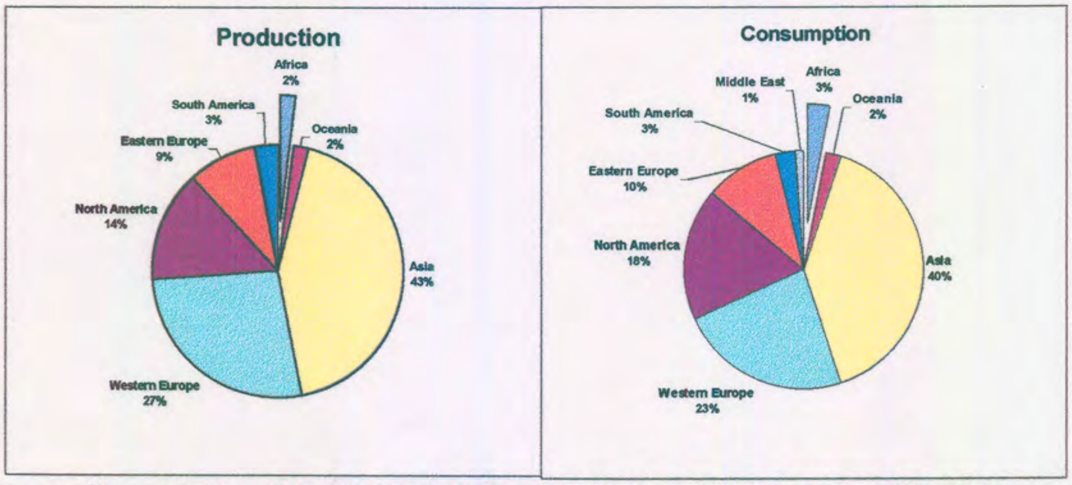
2. THE BUSINESS ENVIRONMENT

2.1 THE MARKET ENVIRONMENT

A total of 37 million tons of welded tube and pipe is produced globally per annum, of which about 10 million tons (27%) is traded internationally. South Africa produces about 500 000 tons annually of which 20% or 100 000 tons are exported to foreign markets. Robor Tube produces approximately 150 000 tons per annum and exports 30 000 tons (20%) of this annually. The overwhelming majority of Robor Tube's exports travel beyond South Africa's immediate neighbors to Europe and North America.

The charts in **figure 1** shows that production and consumption figures for each of the major regions do not differ significantly. The reason for this is that the profitable marketing of tube and pipe is extremely sensitive to transport cost. The result of this is that most of the trade is intra-regional.

Figure 1: International Welded Steel Tube and Pipe Production and Consumption by region.



Source: Blueprint Consulting (Pty) Ltd, *Carbon Steel Tube and Pipe Initiative*, 1997. (P18)

The demand for welded tube and pipe follows the commodity cycle, but the product is in the mature state of its product life cycle. The product life cycle in South Africa lags the Developed World by about eight years. The global trend in the demand for steel tube and pipe is declining, because of substitution. Because of this, Robor Tube will have to react quickly in order to keep up with the pace of transition.

In comparison to the decline in demand for steel tube and pipe, the demand for the same product made from competing materials, is still growing. Significant substitution is taking place and this trend looks set to continue as new, more advanced materials are being developed.

Over the last twenty years steel tube and pipe manufacturers have enjoyed a slight edge in pricing over their raw material suppliers. However, since 1990, the trend has reversed and all the competitors in the local market have felt a squeeze on margins.

From the above it is obvious that there are tremendous pressure on Robor Tube from the market environment. Volumes are declining, prices are extremely competitive and competition is fierce. It is therefore essential that Robor Tube ensure that their operations are able to withstand the pressure.

2.2 THE PRODUCT

Robor Tube manufactures welded hollow sections from carbon steel, largely sourced from Iscor, South Africa's main steel producer.

Raw material consists of hot-rolled carbon steel coil of thickness 1,5mm to 7.1mm. A variety of steel qualities are used, for example SAE1008, 300WA, BS1449, SAE1010, Supraform TM380 and CortenA.

Products can be classified in three major groups:

- Load bearing structural tube (ungraded);
- Load bearing structural tube (graded);
- Conveyance pipe.

Non-graded structural tube can be manufactured in three possible profiles, namely round, square and rectangular. Sizes vary from 21,43 mm outside diameter to 152 mm OD and thickness from 1,5mm to 2.8mm.

Graded structural tube can be manufactured in the above-mentioned profiles in sizes of 60,33m OD to 219 mm OD and thickness of 2,8 to 71 mm.

Conveyance pipe can be manufactured in sizes from 15-mm nominal bore to 200-mm nominal bore. Conveyance pipe is normally pressure tested according to quality specification standard (SAB62, ASTM, BS1387 etc).

Steel tube and pipe are manufactured by plastically deforming a flat steel strip into a round section. The open section is then welded by means of an Electric Resistance Welding process.

Transformation processes include galvanising, painting, threading, and coupling.

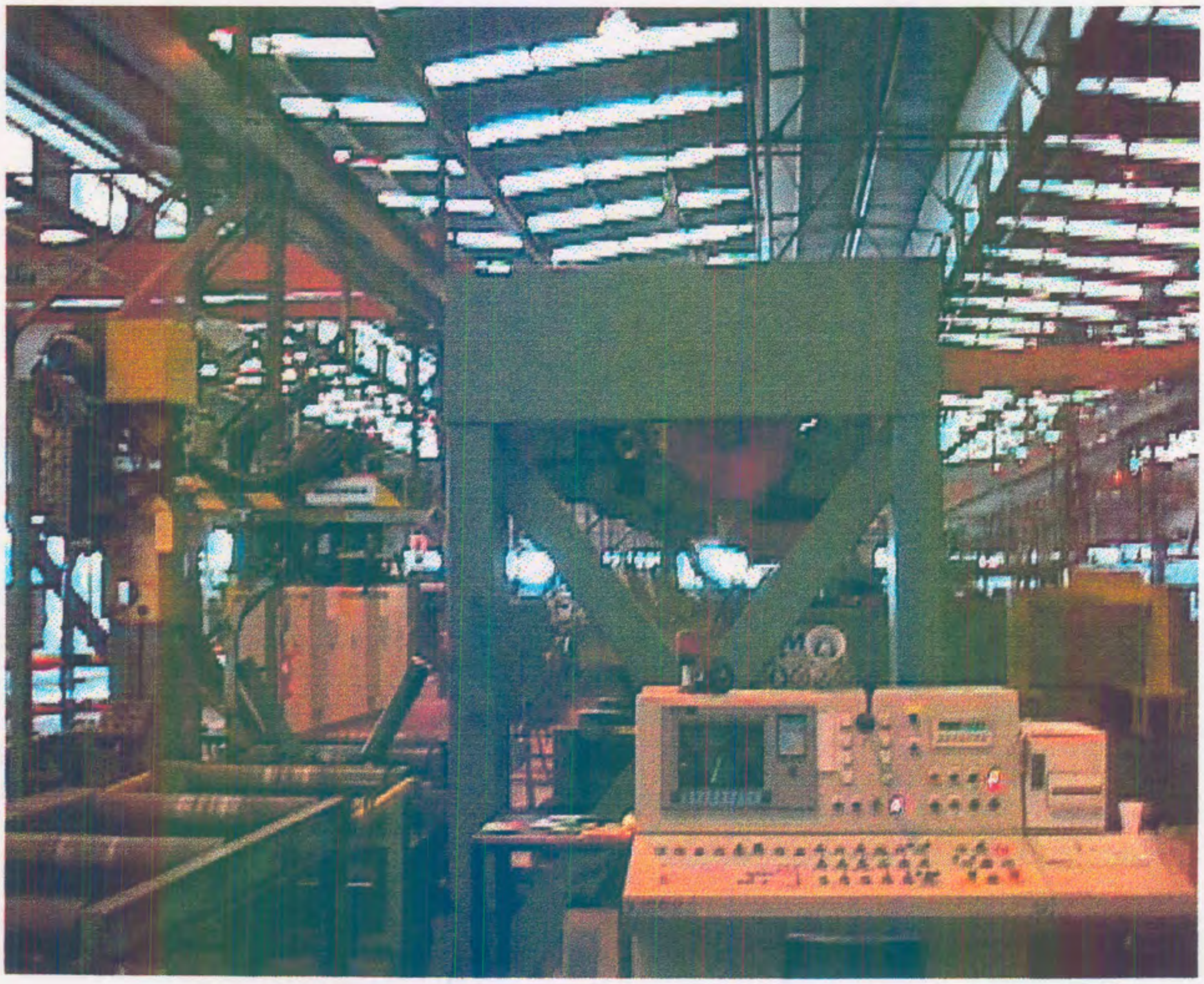
2.3 THE PROCESS

Steel coil is cut to a specific size by means of a mechanical rolling blade process. The flat strip is then plastically deformed into an open round section by means of a series of driven roll-sets. The edges are then forged together by means of an ERW (Electric Resistance Welding) process. This is done by means of a high-frequency induction welder. The closed hollow section then passes through a set of sizing and profiling roll-sets. The tube is cut by means of a flying sheer.

The quality of the weld seam is tested by means of the following processes:

- Magnetically induced eddy-current testing in the case of structural product;
- Hydrostatic pressure testing in the case of conveyance product.

3. What to change?



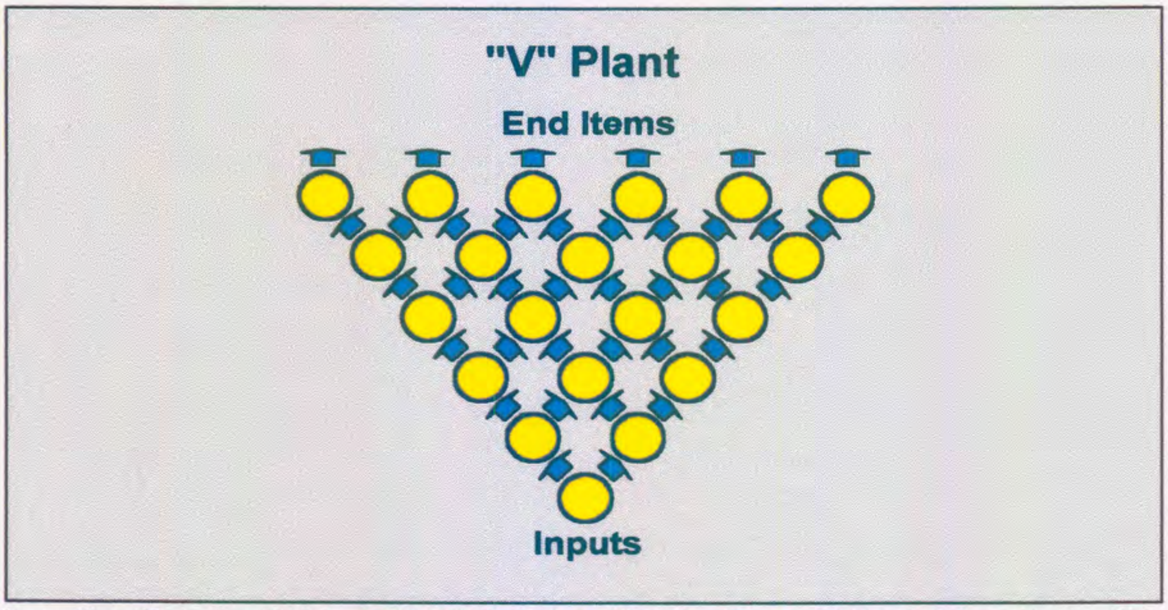
3. *WHAT TO CHANGE?*

The first paragraph in this discussion will show how a theoretical model of the product flow can be used as basis for problem analysis at Robor Tube. The following paragraphs will then discuss specific problems at Robor Tube, and what the causes for those are.

3.1 *VAT CLASSIFICATION*

Chase, Aquilano and Jacobs (1998:810) argues that all manufacturing plants can be classified into one or a combination of three types, designated V, A and T, depending on the products and processes. The reason for the classification is obvious when one notes the actual appearance of the product flow through the system. **Figure 3** shows a typical "V"-plant.

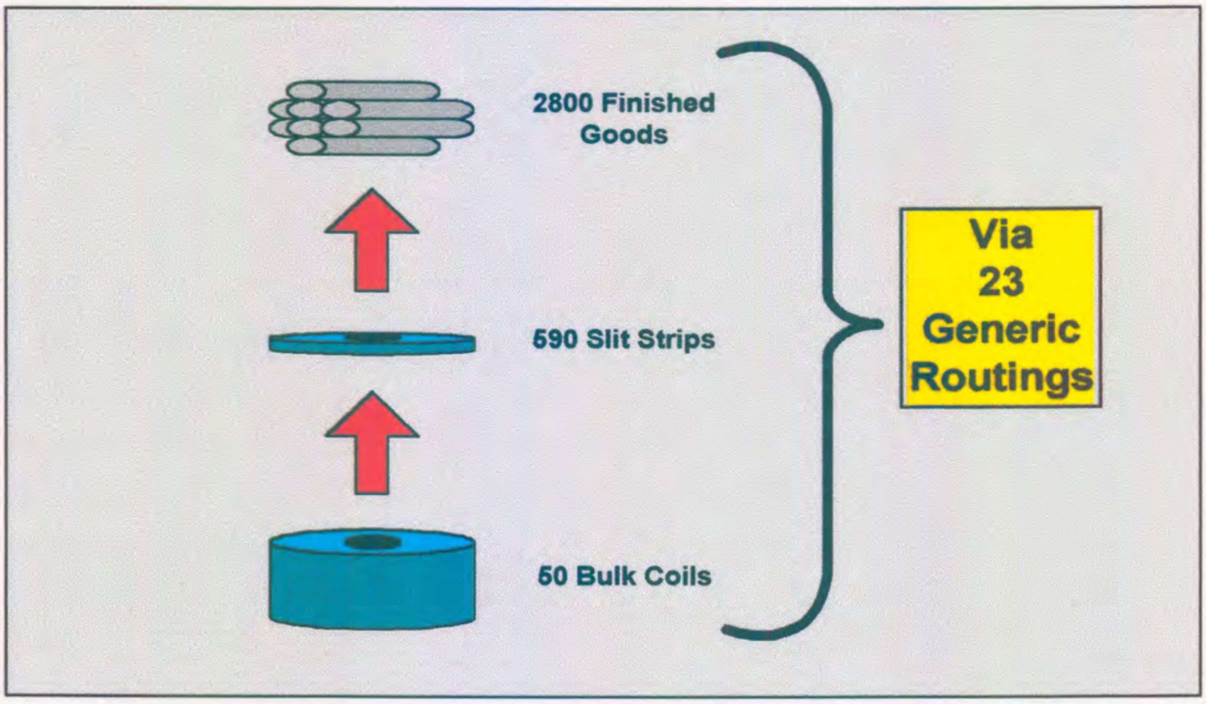
Figure 3: A Typical "V" Plant



Source: Chase RB, Aquilano NJ & Jacobs FR, 1998. ***Production and Operations Management: Manufacturing and Services.*** **Richard D Irwin Inc.**

Chase *et al* (1998:811) describe a "V"- plant as a plant where there are few raw materials that are transformed through a relatively standard process into a multitude of finished products. If one considers the process at Robor Tube and a finished-goods item master of more than 2800 items, it conforms to the characteristics of a "V"-plant, as illustrated in **Figure 4.**

Figure 4: Robor Tube's item relationship



"V"-plants experience the following generic problems (Chase *et al* 1998:812):

- Excessively large finished-goods inventory;
- Customer Service/On-time delivery is relatively poor;
- Manufacturing complaints that the demand is constantly changing;
- Marketing complains that manufacturing isv slow to respond;
- Inter-departmental conflicts are common;
- Production lead times become unpredictable.

Since Robor Tube can be classified as a "V"-plant, the problems experienced are no different from the above-mentioned ones. They will therefore form the basis for answering the fundamental question of "What to change?"

3.2 INVENTORY LEVELS

Goldratt (1986:29) defines inventory to be all the money the system invests in purchasing things the system intends to sell. It is important to note that with this definition, Goldratt includes both finished goods, work-in-progress, raw material inventories, as well as fixed and moveable assets.

According to Vollmann, Berry and Whybark (1997:689), investment in finished goods is consumed by independent demand, which is primarily influenced by factors outside of the company decisions. If we consider the influence of lot-size and production lead-time, it can be argued that the level of finished goods inventory is a consequence of internal production and marketing policies.

The same argument applies for manufacturing inventories (work-in-progress and raw materials). Vollmann *et al* (1997:689) states that manufacturing inventories are directly dependent on internal factors well within the company's control, such as the Master Production schedule and the shop-floor schedule.

Table 5: Inventory levels at Robor Tube

Item	Quantity Tons	Value R
Bulk Coil (Raw Material)	12,928	25,501,348
Slit Strip (WIP)	6,027	13,309,351
Other work in progress	2,500	5,375,000
Finished Goods	11,353	33,204,492
Total		**77,390,191**

For the purpose of this report, the influence of both internal policies and external demand will be considered in evaluating the inventory level of finished goods and manufacturing inventories.

After closer investigation, the reasons for the high stock levels are the following:

- In order to keep utilisation and efficiencies high, sometimes referred to as economies of scale or reducing the cost per unit, batch sizes are increased;
- Because of larger batch sizes, the queues (work-in-progress) increase, resulting in longer lead times;
- The longer the lead times, the slower the response to changes in market demand, because orders have to wait in long queues;
- The decision is therefore made to increase the finished goods inventory to be able to sell from stock, because customers are not prepared to wait too long for a make to order item.

Considering the figures in **Table 5**, there will be a huge advantage in lowering the levels of both finished goods stock and work-in-progress stock. These advantages include the following:

- Reduction in inventory reduces the carrying charges, resulting in an increase in Nett Income, return on investment and improvement in cash flow;
- Reduction in inventory dramatically reduces the indirect impact, or cost of complexity.

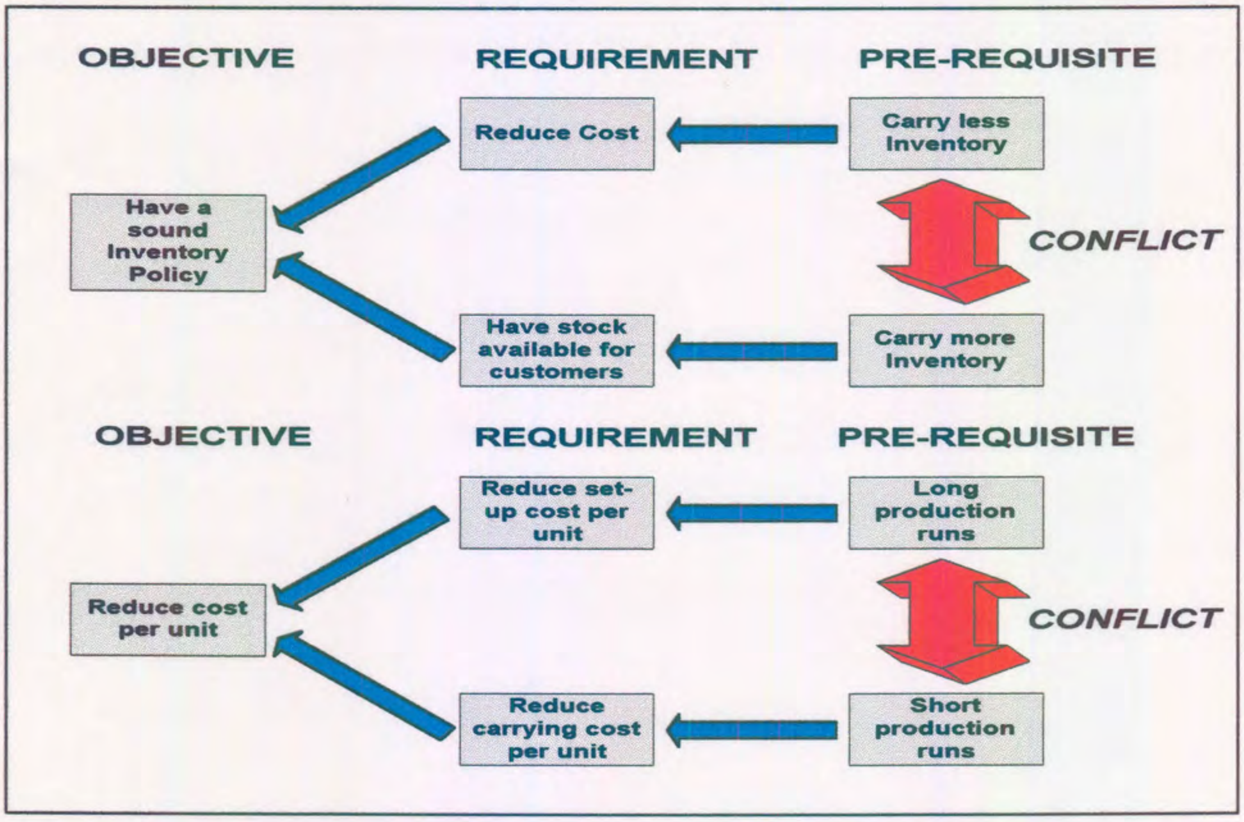
A reduction in inventory also affects so-called intangible factors, related to the competitiveness of the organisation. According to Goldratt (1986:36-66), a reduction in inventory also lead to the following:

- Improvement in quality;

- Reduction of the break-even point, leading to improved margins;
- Lowering investment in equipment and facilities;
- Reduction in manpower requirements;
- Improved due date performance;
- Shorter lead times.

Using the technique of cause and effect diagrams (Goldratt 1990:36), it can clearly be shown that conflict exist in the process of setting an inventory policy. **Figure 6** shows the cause and effect relationships that affects inventory policy.

Figure 6: Conflict in determining Inventory policy



If the facts stated are carefully considered, the only conclusion of this discussion is that the policy of governing inventory in Robor Tube, needs to be revisited, considering all conflicting factors.

3.3 DUE-DATE PERFORMANCE

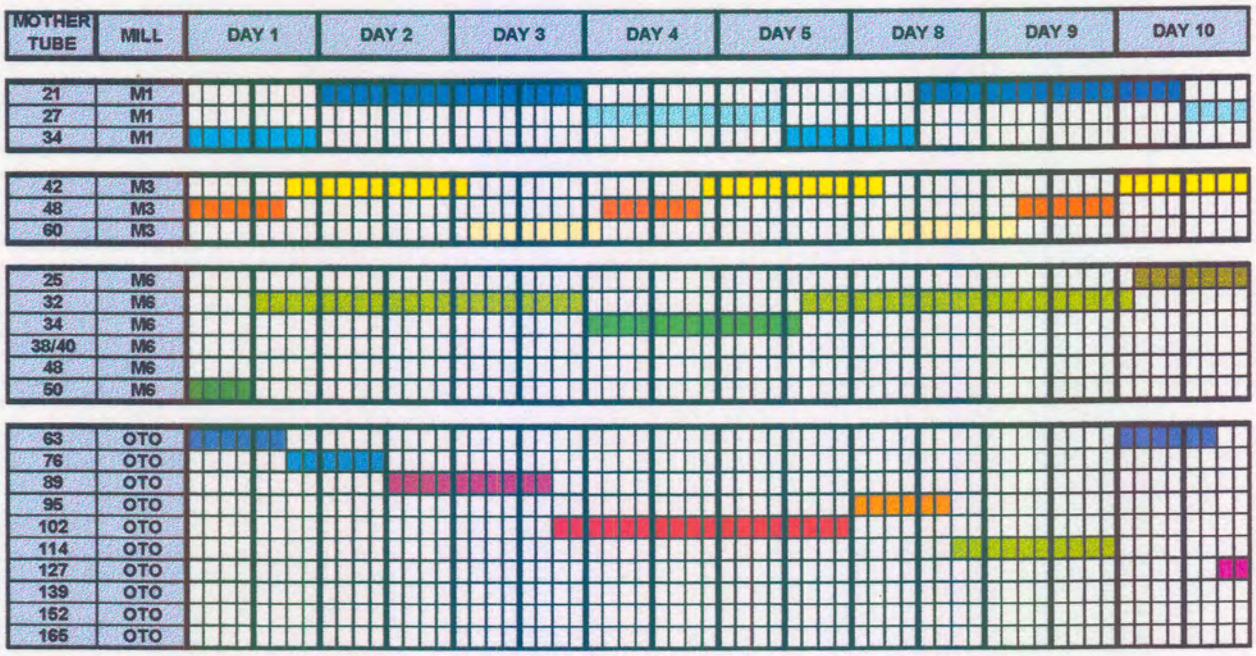
It is obvious from the discussion above that Robor Tube compete in a very competitive market. Goldratt (1994:272) states that the market punishes companies that do not satisfy the market perception of value. In a review of the logistic challenges and opportunities facing industry in the South African marketplace, Franz, Cilliers and Andrews (1995: 37) concluded that the provision of a reliable service is almost more important than price. The result of the survey indicated that the companies under investigation were prepared to pay extra for reliable delivery.

Due dates in Robor Tube are based on a fixed rolling schedule, where a predetermined production cycle repeats itself every two or three weeks. The fixed rolling schedule is based on the following assumptions:

- Demand takes up capacity in the rolling schedule based on an average production rate;
- The length of a rolling program is fixed and based on the proportionate demand for the specific product size. The demand is assumed constant;
- The tube mills are the only factor that determines the schedule, and the down-stream transformation units are disregarded in total;
- All required material for a specific rolling schedule will be available at the planned production time.

An example of the fixed rolling schedule can be seen in **Figure 7**.

Figure 7: Robor Tube's fixed sequence rolling plan



The result of the above-mentioned process is that instead of the desired fixed rolling program, exactly the opposite happens, namely a continously changing program. The reason for this is the fact that the assumptions that drive the schedule, are not correct.

The incorrect assumptions are:

- Production rates are subjected to statistical fluctuations that will also cause demand on the capacity to fluctuate;
- Demand is not fixed and is subjected to fluctuations. The demand cannot be used to determine the length of the rolling and the ultimate lead times;
- Lead times cannot be accurately predetermined. It is a function of the way that the plant will be scheduled;

- The disregarding of down-stream operations in the schedule, is equivalent to disregarding the dependencies between units in a system;
- Material availability cannot be guaranteed if the dependent demand is not actively managed.

Because of a continuously changing schedule and due dates determined on a fixed schedule, poor results are to be expected. Due date performance is far from ideal. Therefore, the methods used for scheduling and determining due dates at Robor Tube, need to be refined.

3.4 MEASUREMENT

Measurement is a direct result of the chosen goal (Goldratt 1990:14). It must be noted that measurement determines behaviour. Therefore, if wrong things are being measured, the behaviour and outcomes will be wrong.

The income statement of Robor Tube is structured in such a way that the Nett Income of the company is dependent on the cost recovery on manufacturing equipment. This recovery are directly proportional to the volume of material that has been converted in a given time period. The volume of product produced is the yardstick by which the manufacturing is measured. The goal is therefore to produce as much as possible.

The manufacturing environment in Robor Tube is measured by the following:

- Machine utilisation;
- Efficiency of production;
- Volume produced;
- Material yielded.

These measurements are not new in the manufacturing environment and will probably be used in the majority of manufacturing as the measurement of success. However, on closer examination, it can be shown that the assumptions on which these measurements are based, are not always supportive of the goal of the company. The measurements also result in many undesirable effects.

To achieve high utilisation figures, the machines are kept busy at all times. If a lack of demand exists, future-dated orders are manufactured. Set-ups are kept to the minimum and production runs are scheduled to be as long as possible.

Efficiency, which is a measure of adherence to standard production rates, results in supervisors running the machines at maximum tempo. In some instances, efficiencies of greater than a 100% are achieved. This of course implies that the machine is operated on the limit of its design parameters, for the sake of achieving admirable utilisation. In some instances, the processing equipment (Hydrostatic tester, End-face machine etc) become constraints, in other words, the mill produces more than what the processing machines can manage.

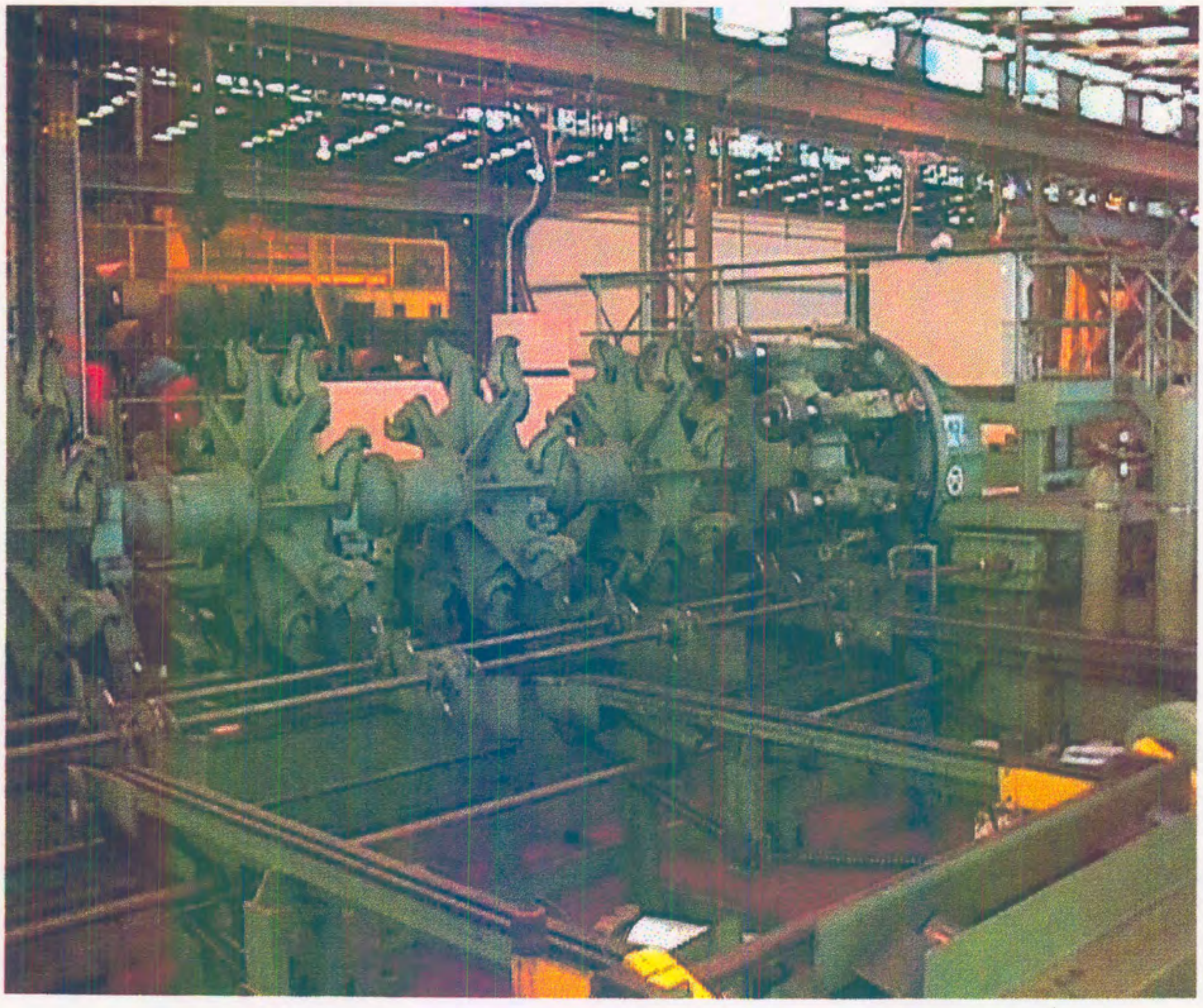
Limited demand in the manufacturing environment however causes the chasing of measurements to have the following effect:

- Excessive levels of work-in-progress;
- Excessive levels of finished goods;
- Long lead-times;
- Poor due date performance;

Only when the outcomes of the measurements are considered, does it become obvious that having the wrong result in an undesirable situation.

If we return to the statement that measurements are a result of the system's goal, the conclusion therefore must be that the goal is wrong or that the company has the incorrect measurements for the correct goal. A new goal needs to be defined and new measurements derived.

4. What to change to?



4. WHAT TO CHANGE TO?

4.1 THE ORGANISATIONAL GOAL

In the preceding sections, it was clearly pointed out that Robor Tube is competing in a tremendously competitive market. The struggle to survive in such an environment is becoming increasingly difficult. Robor Tube is wholly owned by Robor Industrial, which forms part of the Barlows Industrial conglomerate. Shareholders in Barlows, a publically listed company, have only one goal in mind, namely the making of money! Shareholders do not appreciate excuses for poor financial performance and will simply withhold their investments if the return on equity is not adequate.

The goal of the company therefore is not only to survive, but also to grow. The only tangible derivative of this goal is to make money presently and in the future. This is the only goal that will guarantee the support of not only the shareholders, but of all stakeholders in the company.

The goal of making money presently and in the future, is supported by three bottom line measurements:

- Net Profit – An absolute measure;
- Return on Investment – A relative measurement;
- Cash Flow – A prerequisite to survival.

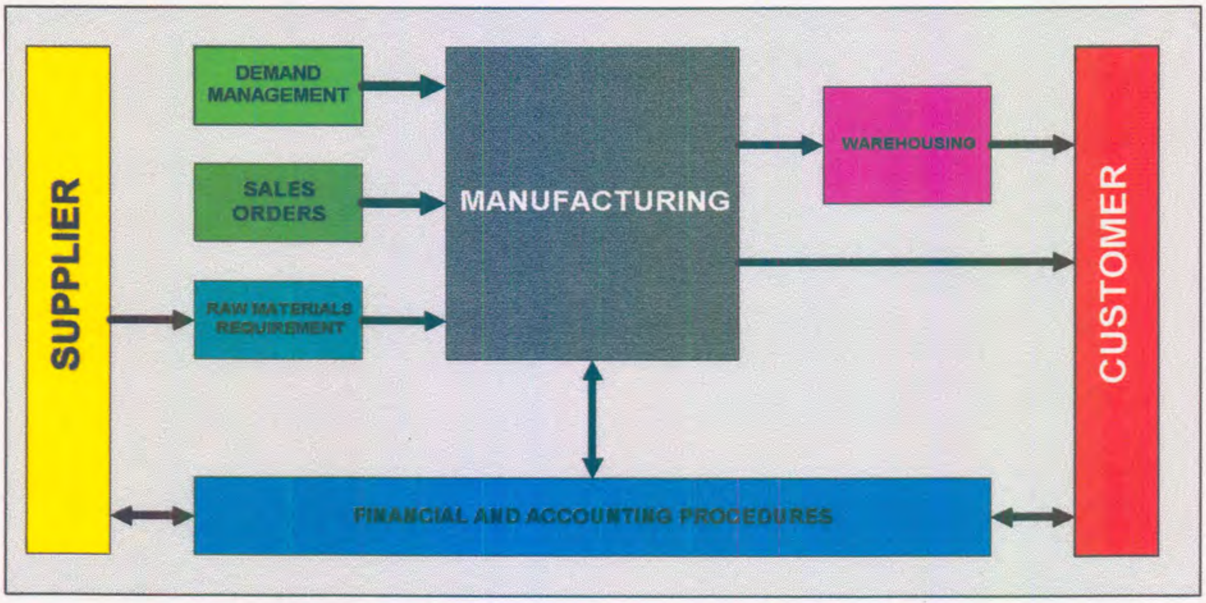
No other goal or measurement is more important than those mentioned above. The operational measurements should therefore attempt to improve the bottom line measurements as listed above. If any operational measurement does not attempt to improve any one of the bottom line measurements, its outcome is of no value and will probably have the opposite effect.

4.2 AVAILABLE SYSTEMS

As previously mentioned, Robor Tube installed an ERP (Enterprise Resource Planner) during 1997. The initial implementation however only dealt with the modules related to finance, sales and distribution (warehousing). The manufacturing environment continued to operate as a separate entity with very little transparency. A multitude of manual planning and control systems still regulates the manufacturing facility, without any interaction with the front-end systems.

It is therefore fair to describe the manufacturing environment as a "black box" that produces tube and pipe, based on inputs from a sophisticated order acceptance system.

Figure 8: The current manufacturing environment



It is important to note the following regarding the current manufacturing environment:

- Firm orders from known customers are accepted by means of the sales order which is being processed in the Baan-ERP system;
- Forecast of demand from random customers is done by means of a stand-alone system named Execulink. Execulink uses manual inputs of sales history and statistical forecasting processes like exponential smoothing, moving averages, etc.
- Raw material inventory is maintained within the Baan-ERP system. Stock levels, consumption and replenishment of raw material is regulated outside of the system from within the manufacturing environment. These processes are manual spreadsheet driven procedures that generate the expected demand for raw materials. The Baan-ERP system therefore is only used as an electronic inventory record.
- Direct labour and the administration there-of, are done externally in a manually driven payroll-system. The cost of labour is seen as an input to the process.
- Purchase requirements, regarding consumables and engineering spares, are processed by means of the purchase order module within the Baan-ERP system.
- Finished goods are booked into the distribution centre, where operations are controlled by a sophisticated Warehouse Management System. An interface exists between the warehouse management system and the Baan-ERP system. Inventory levels are therefore visible in the Baan-ERP system to enable sales personnel to sell out of stock.
- The fulfillment of a sales order only happens when goods are delivered to a customer.
- Work-in-progress within the manufacturing facility is evaluated on a quarterly basis by means of a physical stock count. Work-in-progress levels are not visible in the Baan-ERP system. Instead, a manual system of spreadsheets is used in an attempt to control WIP levels between the manufacturing facilities.
- No financial integration exists between the manufacturing environment and the General Ledger in the Baan-ERP system. The general ledger reflects production cost at an average conversion rate across the whole product range.

Multitudes of manual systems drive and control the activities within the manufacturing environment:

- A Clipper-based job-card generating system;
- A spreadsheet-based system to plan purchases of raw material;
- A spreadsheet-based capacity modeling tool;
- A manual order tracking system;
- An efficiency measurement system.

It is obvious to conclude that very little integration and transparency can be derived from the system. It consists of fragmented islands of information with limited responses. Management information is poor by modern standards and makes planning and control an almost impossible task.

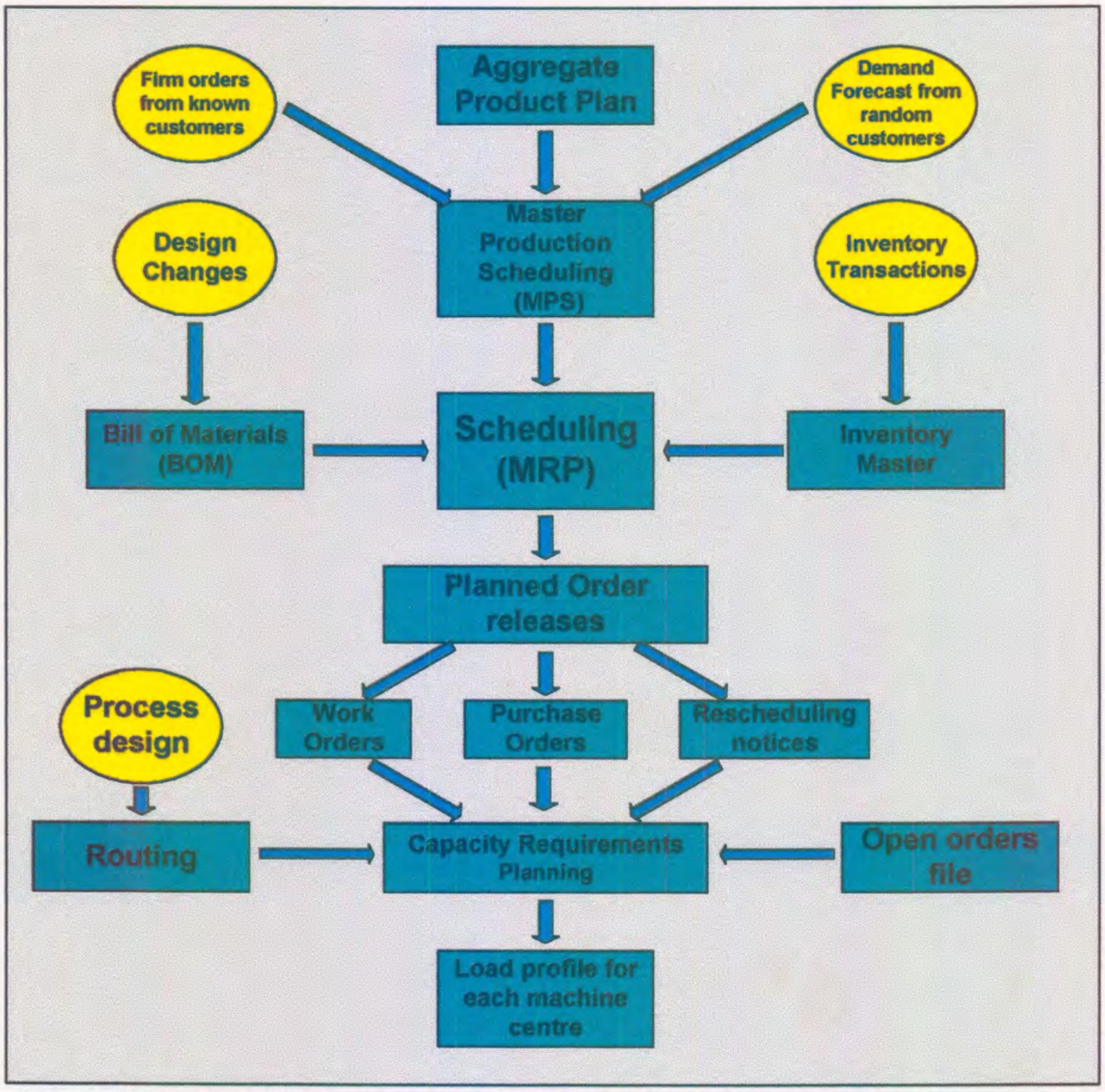
4.3 MANUFACTURING RESOURCE PLANNING-MRP II

The issues discussed above are not unique to Robor Tube. Since the 1960's, production managers struggled with similar problems. Material Requirements Planning (MRP) was developed to feed orders to the production floor based on the demand of a parent item. This was a first attempt to plan and control production facilities and scheduling the shop floor using derived or dependent demand.

Further development continued and Oliver Wight developed an enhanced version of MRP that closed the loop to non-manufacturing functions like marketing, finance and purchasing. This is referred to as Manufacturing Resource Planning (MRP II). Schonberger and Knod (1994:331) quotes Wight: *MRP II results in management finally having the numbers to run the business* and *MRP II serves as a company game plan*. Vollman *et al* (1997:392) states that the intent of MRP II is to clearly delineate the integral relationships between manufacturing planning and control systems, marketing systems and financial systems.

For the past three decades, MRP II has been used as the primary model upon which manufacturing organisations formulated their processes. With the arrival of cheaper computing power in the 1980's, MRP II systems dominated the production environment. Goldratt (1986:10) claims that more than $30 billion was invested in computers and MRP II-based software before 1985. **Figure 9** depicts the basic MRP II logic.

Figure 9: Generic MRP II Logic



Source: P.J.Pretorius, 1999. Operations Management. Study Notes. University of Pretoria.

MRP II can be seen as a process divided into the following steps:

1. A master plan is generated for items based on actual and forecasted demand (independent demand);
2. It then explodes the dependent demand based on a Bill of Materials (BOM) and current inventory levels;
3. By considering the routing detail, capacity requirements are planned and machines are scheduled;
4. Planned purchase and work orders are generated

The manufacturing module of the Baan-ERP system uses MRP II logic to plan and control the manufacturing environment. It consists of three fully integrated systems, namely a master production scheduler (MPS), a material requirement planner (MRP) and a shop-floor controller.

These three sub-systems uses an item master file, a Bill of Material file (BOM) and a routing file. The manufacturing module is fully integrated to other organisational functions like finance and distribution.

Because of the success of the implemented finance, sales and distribution modules, management opted to use Baan Manufacturing as the system to close the loop between sales and the distribution facility.

4.4 THEORY OF CONSTRAINTS (TOC)

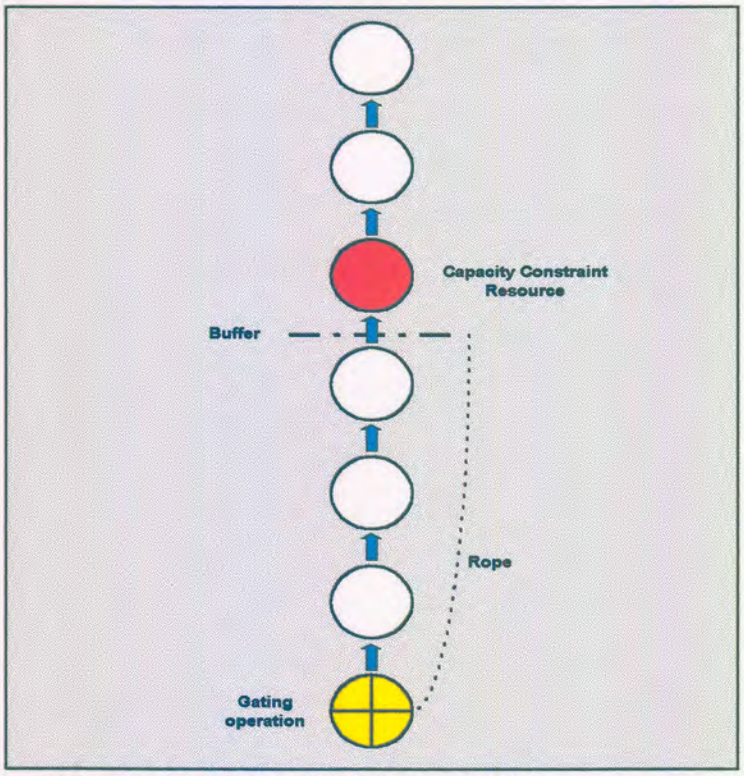
In 1984, an Israeli physicist, Eliyahu Goldratt, introduced a new theory to the manufacturing environment called "Theory of Constraints" or TOC. TOC is a verifiable philosophy with the acknowledgement of cause and effect as a central concept and the fact that conflicts do not exist in nature. TOC is a set of problem-solving tools or thinking processes that provide the ability to recognise the paradigm shifts that occur when times change, but not our assumptions and rules.

Although TOC provides us with solutions for all the normal business functions (Marketing, Sales, Distribution, etc), this report will focus on the manufacturing concepts within the theory. As far back as 1985, Japanese companies introduced the concept of synchronized manufacturing. Goldratt (1986:70) defines synchronized manufacturing as any systematic way that attempts to move material through the various resources of the plant in concert with market demand.

Goldratt developed a system of synchronizing a manufacturing plant, called the Drum-Buffer-Rope approach. The approach is based on the assumption that every plant has a bottleneck or resource constrained by capacity (CCR). Since the bottleneck or CCR is the weakest link in the system, it should dictate the pace of the proceedings.

A Drum-Buffer-Rope system can be illustrated by means of the following diagram:

Figure 10: A Generic Drum-Buffer-Rope System



Source: Goldratt EM, 1986. The Race,(p101)

The fundamentals of DBR-systems are the following:

- The bottleneck or constraint resource should dictate the schedule based on market demand and its own potential. It is the drumbeat on which the other resources march;
- The schedule for future operations should be derived accordingly. In other words, downstream operation should be forward-scheduled-based as the output of the bottleneck or CCR;
- The schedule of preceding operations should support the time buffer and thus be derived backwards in time from the bottleneck or CCR schedule. In other words, "a rope" tied from the bottleneck to the first operation, should regulate the tempo of the first operation. The first operation is therefore referred to as the gating operation;
- In order to protect the bottleneck from disturbances that might occur at the preceding operations, a buffer is created before the bottleneck resource. Any unforeseen disruptions can be overcome within the time buffer and therefore will not affect the throughput of the plant. In **Figure 10**, it is represented by the amount of slack in the rope.

The DBR method has the following advantages:

- ***DBR protects current throughput:*** Since the bottleneck, which determines the pace of proceedings, is protected against any unforeseen happenings in the preceding operations, the majority of disruptions can be overcome within the predetermined time interval. In other words, the time buffer in front of the bottleneck or CCR will protect the flow of products through the buffer, and consequently the throughput of the entire plant;
- ***DBR reduces inventory:*** The rope tied to the gating operation determines the pace at which work would arrive at the bottleneck or CCR. Since all the operations preceding the bottleneck or CCR have capacity greater than that of the CCR, no inventory will build up between the preceding operations. The same principle applies to operations following the bottleneck or CCR. The buffer directly

preceding the CCR is the only point where inventory can build up, and then only to protect the CCR against unforeseen events for a predetermined time interval;

- ***DBR protects customer due dates:*** The schedule of shipping products out of the last operation is dictated by the availability of scarce parts coming from the CCR. If a buffer is created to protect the supply of products to the last operation, coming from non-constrained resources, the on-time delivery of products to customers is protected against disruptions in non-constrained resources. Every part, in its journey from raw material to finished goods, will only pass through one buffer.
- ***DBR does not increase operating expense:*** No additional operation is necessary to implement DBR. In any plant, no matter how large or complex, there is only a limited number of CCR's. A time buffer can protect every CCR and so can the operations fed by them. Ropes can be tied from each buffer to the gating operations. All of the above can be achieved without the addition of any additional operating expense.

It can be concluded that the DBR-system can generate a schedule that will increase the probability of completing the order within the scheduled time. The increase in probability will improve the way in which the manufacturing environment satisfies the requirements of the market. Gardiner, Blackstone and Gardiner (1993: 13) concludes that DBR provides a framework which distils the complexities of material flow into an understandable format:

- DBR drastically reduces the number of resources that must be explicitly scheduled;
- DBR warns of potential disruption to the production plan by means of the time buffer;
- DBR aligns local resource performance-measures with global organisational performance.

Although the philosophy of the DBR logistical system is quite clear, and the calculations straightforward, the complexity of a specific manufacturing environment may need the aid of a computerised system.

4.5 A HYBRID MRPII SYSTEM AND TOC

The MRPII system is a planning system, with the goal of delivering the correct quantity of material at the correct time, based upon orders combined with forecast (Vollmann, Berry and Whybark 1998). TOC is a management philosophy, with the goal of making money, in both the present and the future (Smith 1994:1). The key insight of TOC is that only a few work-centers within any manufacturing environment control the output of the entire system. Managing these constraints or bottlenecks optimises the output of the entire system.

Because MRPII arrived before TOC, TOC has generally been implemented with an MRPII system already in place. In the literature that has been reviewed, TOC has been viewed as complementary to MRP. Chase, Aquilano and Jacobs (1998:822) present the case of the Frame Company. They have used the Master Production scheduling (MPS), the Material Requirement planning calculation module (MRP), the financial accounting module, and the bill-of-material (BOM) of an MRPII based software system. However, for shop floor scheduling and control, they have used the TOC method. Management of the Frame Company believed that the MRPII system provided a framework for a TOC-based shop floor system. The shop floor is controlled by a Drum-Buffer-Rope scheduling system.

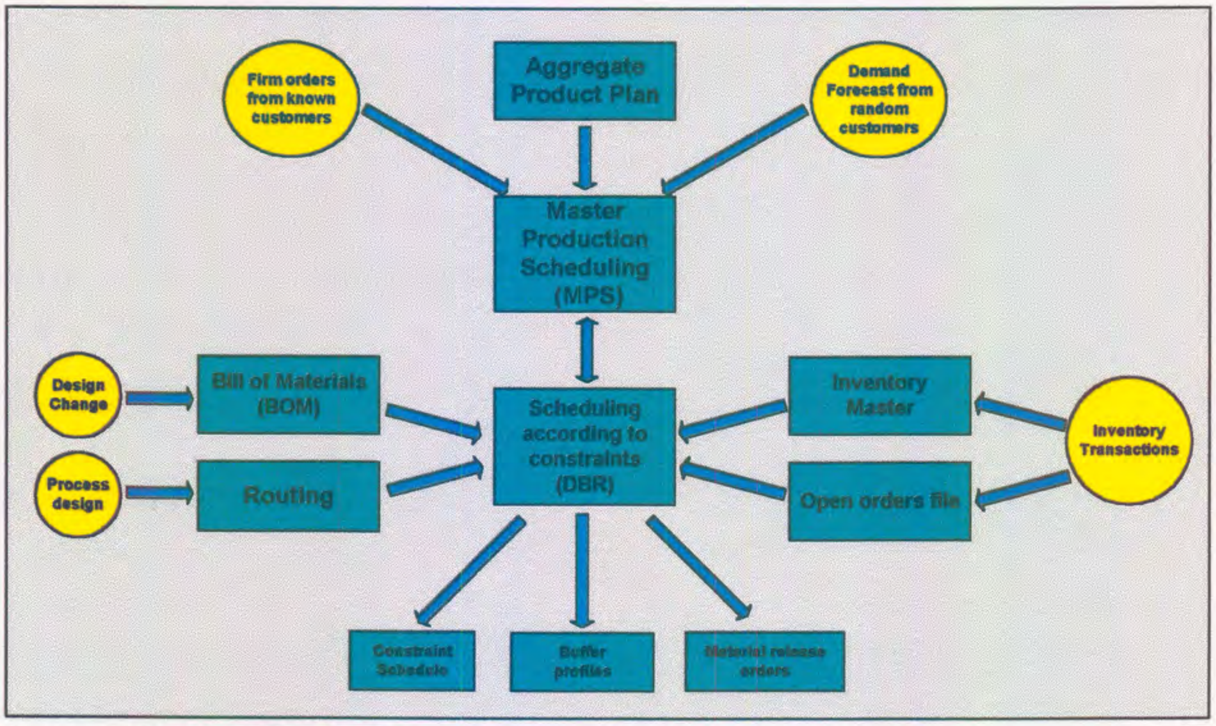
Vollmann *et al* (1997:795) views the TOC and the Drum-Buffer-Rope scheduling method as an enhancement to MRPII's production management and control system. They define TOC's primary contributions as follows:

- Finite scheduling considering the capacity constraint of bottleneck resources, produces a do-able production schedule.
- The way that TOC and DBR scheduling deals with non-bottleneck resources, result in less work-in-progress, reduced lead-time and greater material velocity.
- TOC and DBR scheduling virtually eliminate the fundamental issue of conflicting priorities between MRP and finite loading.

Smith (1994:6) concludes that a combined system of MRPII/TOC, TOC uses MRP to order materials. The planning system is a modified MRP system with an aggregate production plan, a stable MPS, a Bill of Materials, and a set of time-phased orders. The short-term planning and execution is done through a drum-buffer-rope (DBR) system. One of the biggest advantages, however, is that with DBR scheduling, the validity of the MPS can be checked as opposed to MRP, where a valid MPS is assumed. The capacity requirement plan and the rough-cut capacity are determined by using DBR. The MPS is driven not by customer orders, but by the bottleneck or CCR.

Figure 11 shows a model where a Master Production Schedule (MPS) deals with the independent demand from the external environment. The dependent demand for capacity and material in the internal environment is scheduled based on TOC and DBR logic. Note that this model provides for feedback responses back to the MPS. This enables the DBR system to make changes to the MPS if the constrained resources determine it.

Figure 11: A Manufacturing Scheduling Model using MPS and TOC.



Source: PJ Pretorius, 1999. Operational Management, Study Notes, University of Pretoria.

After studying the literature, the conclusion can be made that there seem to be synergies in a combined MRPII – TOC system. It is definitely a "best of both worlds" scenario.

4.6 THE SOLUTION FOR ROBOR TUBE

Under heading 3, the following question was asked: What to change? Three fundamental issues were identified, namely

- Robor Tube needs to change its policy regarding inventory;
- Robor Tube needs to change the way of scheduling and defining due-dates for orders;
- Robor Tube needs to define a goal with measurements supporting the goal that will satisfy all stakeholders.

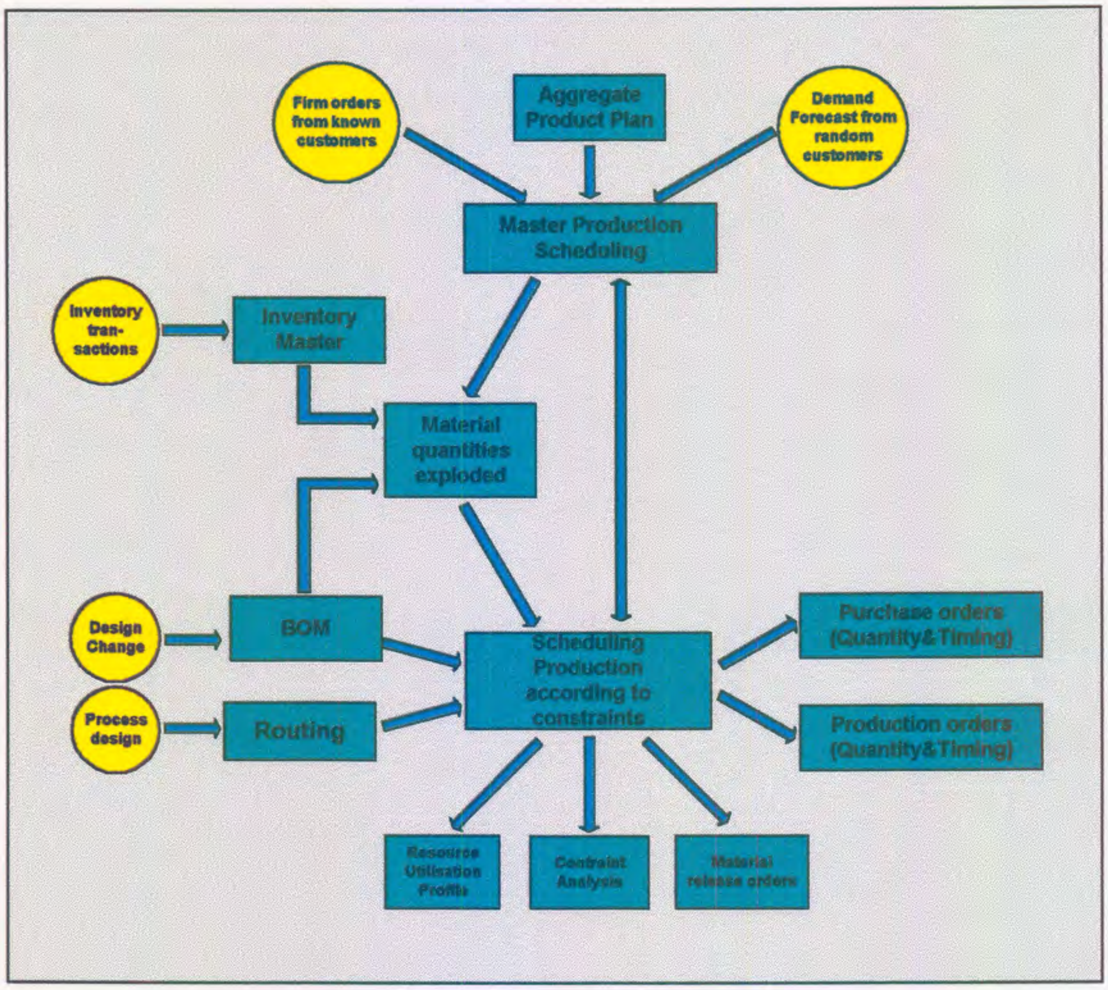
The next step is to ask the question: "What to change to?" Under heading 4.5, three alternatives were identified:

- MRPII-system;
- TOC-based system;
- Hybrid-MRPII/TOC system

Because of the apparent synergies as discussed above, Robor Tube decided to implement a hybrid MRPII/TOC system. The Baan (ERP) with its MRPII manufacturing module, will provide a framework for a TOC-DBR scheduling system to operate in. Baan SCS Scheduler, developed by Berclain in Quebec, Canada, was chosen to handle the finite scheduling of the shop floor. Baan SCS Scheduler uses the Drum-Buffer-Rope theory as its foundation, with a rule-based gradation algorithm to organise set-up on the different work centers.

The advantage of the configuration described above, is that all transactions are integrated with the General ledger in the finance module of Baan-ERP. The diagram in **Figure 12** indicates the relationship between different modules in the manufacturing system.

Figure 12: An Integrated MRPII-TOC model



The above diagram resembles Pretorius's model as depicted in Figure 11. The significant difference is that the quantities of material required are determined before they are scheduled according to the constraints. Required quantities are exploded using the Bill of Material (BOM), and the timing there-of is only determined after scheduling manufacturing resources according to existing constraints.

The results of the model are the following:

- *Purchase Orders* – Quantities determined before scheduling, and timing determined after scheduling according to the existing constraints.
- *Production Orders* – Quantities and due dates determined in the MPS. Shop floor scheduling considers constraints before releasing the production order to the floor.

- *Resource Utilisation Profile* – The loading on each individual work center and employee can be identified. Scheduling according to constraints results in some work centers and employees not being utilised all the time. Resources are only activated according to the needs and outputs of the constraints.
- *Constraint Profile* – Scheduling according to constraint results in a loading profile for the constrained resources. The limitations on the ability of the constraint can then be analysed in order to exploit the constraint to its maximum.
- *Material release orders* – This is the trigger that releases material to the first-in-line operations. In the discussion on TOC and DBR, this operation was referred to as the gating operation. The trigger is dependent on the needs of the constraint, and material releases are tied to the constrained via a "rope".
- *Feedback to MPS* – This output is necessary only if the generated MPS needs alteration. The reason for this may be that the schedule is not feasible, i.e. it is impossible for the constrained manufacturing resources to adhere to the quantities and timing of the MPS.

The business model chosen above will attempt to provide solutions and answers for the identified business issues in the following way:

- **Inventory policy**

  The Master Production Schedule (MPS) is the balancing act between the supply and demand of finished goods. Demand can be defined as the actual orders from known customers as well as the forecast for future orders from unknown customers. Supply of the finished goods is a function of the available capacity on the constraint.

  The level of finished goods inventory is a result of the marketing philosophy and the variability in the supply out of the manufacturing environment. The role of the inventory policy is therefore to create a buffer between what the manufacturing facility produces and what the market consumes. A strong dependency exists between the inventory policy and the due-date performance of the manufacturing facility.

As a result of scheduling the production environment using the Drum-Buffer-Rope method, the due date performance will improve. This will lead to less variability in the supply pattern out of the manufacturing facility, which will stimulate confidence in lower finished goods inventory levels. A more predictable supply out of manufacturing will imply that the inventory policy should only buffer to accommodate variability of the market.

Considering all of the above, the resultant inventory policy should prescribe lower levels of finished goods inventory, because the due-date performance of the manufacturing facility will improve.

- **Due date performance**

The previous method of scheduling was based on a fixed rolling cycle where lead times were pre-determined and unrealistic. The new method of scheduling with Drum-Buffer-Rope (DBR) principles will take cognisance of practicalities within the manufacturing environment. DBR will schedule all manufacturing resources according to the capacity available on the constrained resource, and will create buffers to protect the throughput against unforeseen disruptions in the performance of non-constrained resources. DBR considers the capacity of the constrained resource as well as statistical fluctuations.

If the theory presented in previous paragraphs prevails, there is no reason why due-date performance will not improve.

- **Measurement**

In paragraph 4.1, it was clearly stated that the goal of Robor Tube is to make money presently as well as in the future. Three bottom line measurements, namely Net Profit, Return on Investment and cash flow must support this goal. All operational measurements should therefore attempt to improve these three financial measurements. Although the financial measurements are sufficient to determine when the company is making money, they are inadequate to judge the impact of specific actions.

In the past, the goal was to put as much volume as possible through the plant because it directly influenced the performance on the Income Statement. Production managers were encouraged to achieve high utilisation and efficiency of machines. These measurements are all cost-related, and might lead us to the wrong decisions. In order to measure the effect on the three bottom line financial measurements, Goldratt (1986:29) proposes three global operational measurements:

- Throughput – The rate at which the system generates money through sales;
- Inventory – All the money the system invests in purchasing the things that the system intends to sell;
- Operating expense – All the money that the system spends in turning inventory into throughput.

These three operational measures have a direct impact on the three bottom line financial measurements. When throughput is increased without affecting inventory or operating expense, the Net Income, Return on Investment as well as cash flow will improve. When operating expense is decreased, the Net Income, Return on Investment and cash flow are improved. Decreasing inventory, however, will only influence return on investment and cash flow directly. Net profit will be influenced indirectly if the carrying cost associated with inventory is considered.

In future, activities on the shop floor will be scheduled according to the Drum-Buffer-Rope (DBR) principle. As discussed earlier, DBR scheduling will maximise the throughput in the manufacturing facility because it considers the limited capacity of the constraint. At the same time, inventory will be reduced without any increase in operating expenses. Adherence to the generated DBR schedule is therefore supportive of the company goal of making money, and can be defined as a practical measurement to determine if the manufacturing environment is adding to the bottom line.

Any future improvements should be measured against these three global operational measurements, i.e. throughput, inventory and operational expense. If any future project or acquisition does not increase throughput and/or decrease inventory and/or decrease operating expenses, it is not a feasible project.

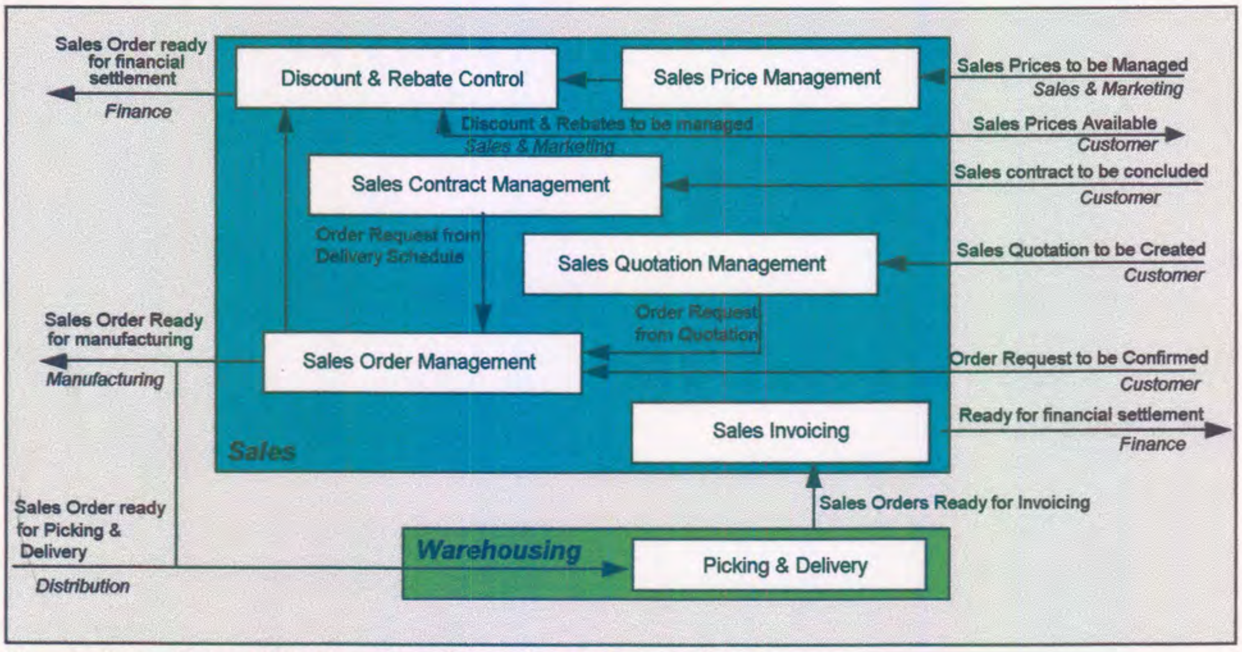
4.7 THE CONFIGURED SOLUTION

This section will point out the complexities of the configured solution for Robor Tube. The discussion will follow the model as presented in **Figure 12**.

4.7.1 FIRM SALES ORDERS

The creation of firm sales orders that are ready for delivery or manufacturing is done entirely within the Baan-ERP. The detail of the sales order process is considered out of the scope of this project, but for understanding, a diagram is included. This clearly indicates the operation of the sales ordering process as well as the interaction with different functions within the business process.

Figure 13: Sales order processing at Robor Tube



Source: Robor Tube, 1999. Manufacturing project documentation.

4.7.2 DEMAND PLANNING

Demand forecasting is necessary for Robor Tube in order to plan capacity and raw material requirements, and to consider scheduling constraints that may exist. In other words, the purpose of demand forecasting is to plan both the quantities and timing of goods to be produced in the short term, inventory and capacity in the medium term and facilities in the long term (Schönberger and Knod 1994:152).

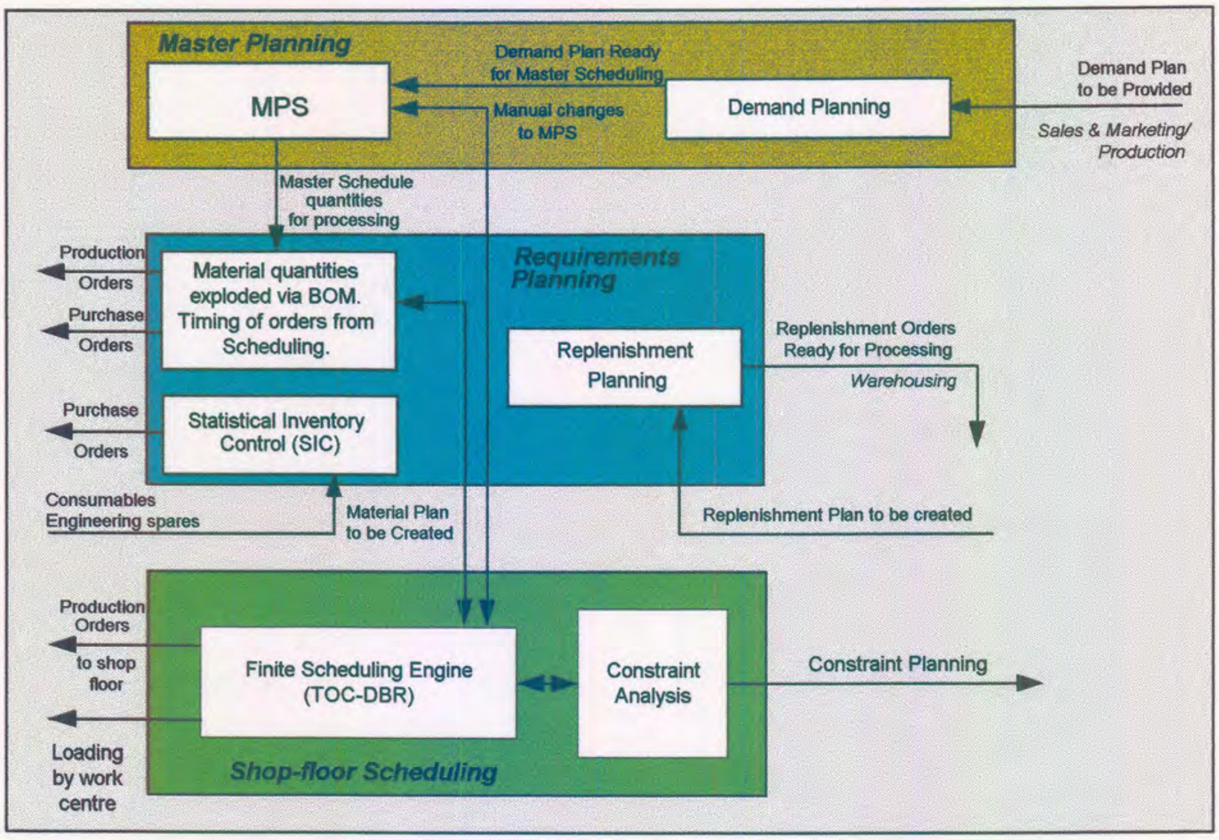
The study of demand forecasting techniques is a complex one. For the purposes of this report, no detail discussion regarding forecasting techniques will be given. Robor Tube chose exponential smoothing as the preferred forecasting technique. It can be described as a weighted moving average forecasting method.

4.7.3 MASTER PRODUCTION PLANNING

Master Production Planning forms an integral part of the planning process at Robor Tube. The master production schedule (MPS) puts actual orders into time slots, and is therefore a statement of production.

Various definitions for what the MPS is and does, exist. Robor Tube developed the following definition: The Master Production Schedule is a time-phased balancing act between the supply and demand of finished good items. These items may be manufactured items or purchased items if they are for resale. Although the majority of the products that Robor Tube provides to customers are manufactured in-house, some is purchased from other manufacturers. Figure 14 shows how the Master-Production schedule interacts with other systems.

Figure 14: Master Planning



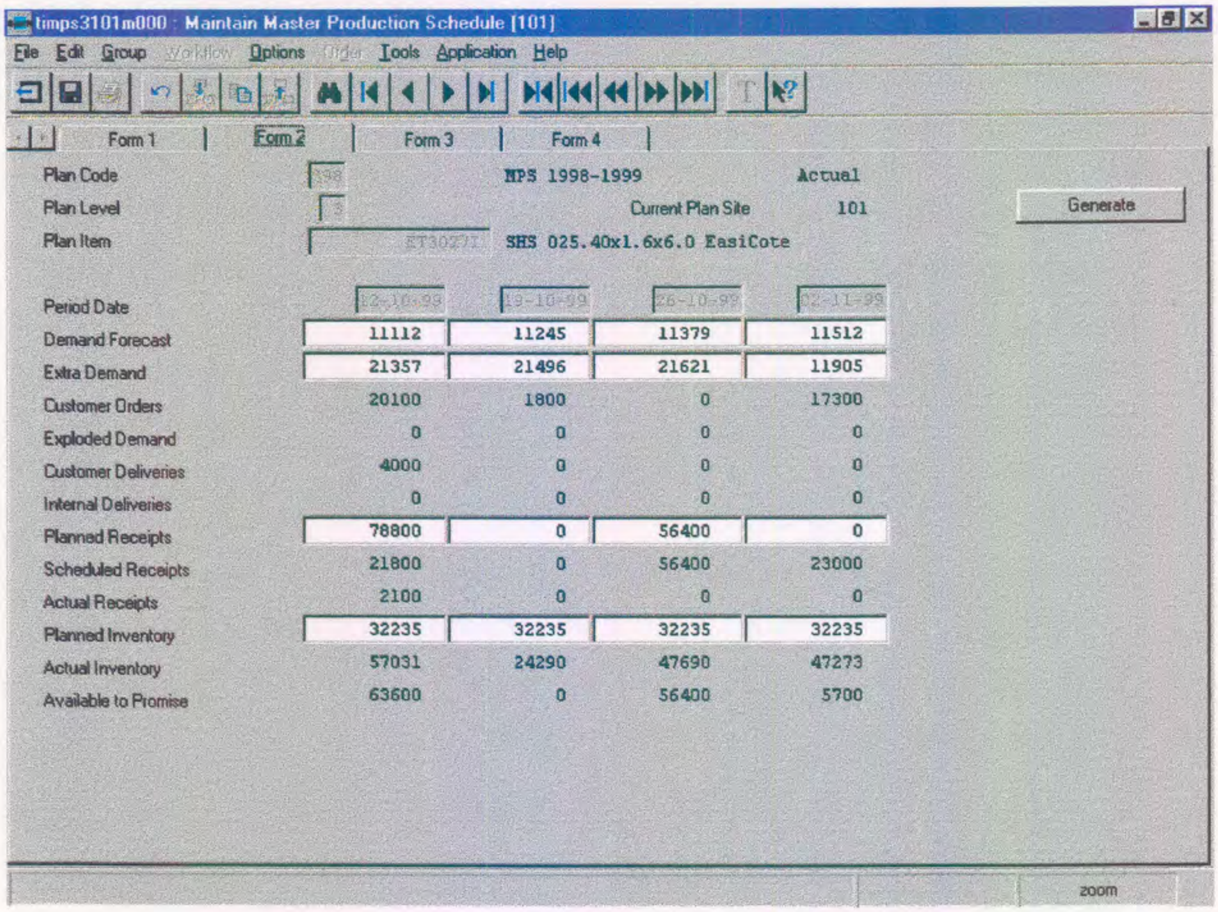
The following aspects of the model should be noted:

No capacity check is present at the MPS level. Normally Rough-cut Capacity Planning (RCCP) forms part of the MPS process. The capacity requirements plan and the rough-cut capacity are fed from the capacity analysis done by the scheduling engine. The finite-scheduling engine operates on the TOC-DBR principle.

The material quantities that are required, are exploded using the Bill of Material (BOM). Only after finite scheduling with the DBR-method can timing be added to the quantities to generate an order.

The Master Production Planning (MPS) module in Baan-ERP is an extremely complicated arrangement of calculations. For the purpose of this report, only a brief discussion of individual line items will be given. **Figure 15** shows the MPS session in Baan-ERP.

Figure 15: The Baan-MPS-module

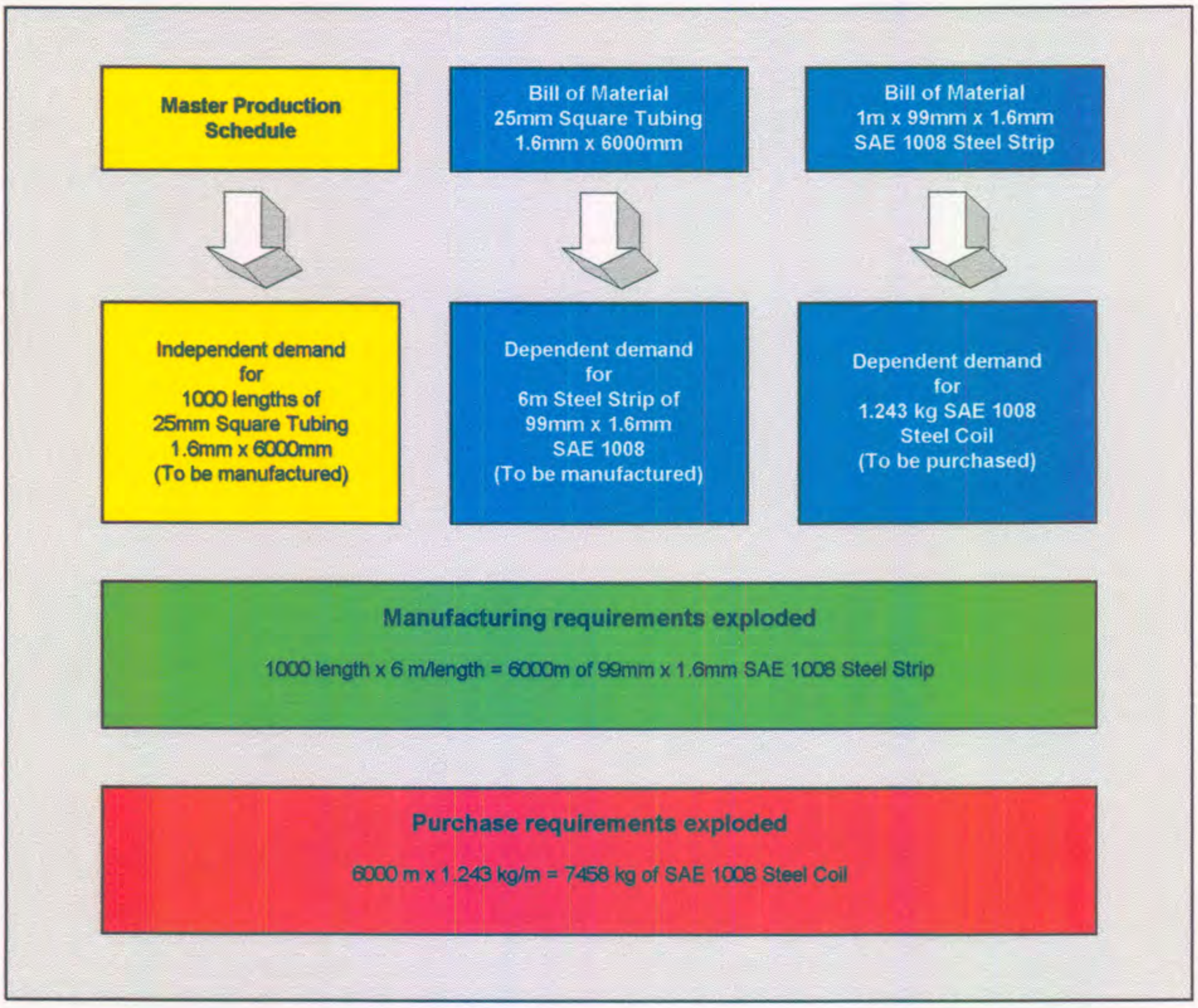


4.7.4 REQUIREMENTS PLANNING

Requirement Planning is a simple concept. Computerized software, like the Baan-ERP, gives manufacturing companies the ability to calculate and aggregate their need for both purchased and manufactured items. Requirement Planning can be described as the explosion of dependent demand as defined in the Bill of Material (BOM). The quantities exploded are based on the independent demand as scheduled by the Master Production Schedule (MPS).

The Bill of Material can be described as dependant demand chain with levels below the end item. By considering the independent demand for items generated by the MPS and inventory records (on-hand balances), the MRP generates the order quantities required for both purchased and manufactured items. This process is referred to as the explosion of the material requirements (BOM). **Figure 16** indicates how the BOM is exploded.

Figure 16 *Explosion of BOM*



In normal MRP II systems, the MRP module calculates the requirements for purchased and manufacturing items by exploding the BOM. These requirements are then grouped into purchase and manufacturing orders that are scheduled for release based on predetermined lead times. Because Robor Tube acknowledges the fact that fixed lead times is unrealistic, the

MRP module of the Baan-ERP system is only used to explode the quantities of the required materials. The timing of orders for purchased and manufactured items can only be determined once the production schedule is known. The finite scheduler (Baan SCS Scheduler), with its DBR algorithm, creates a time-phase schedule for the quantities as released by MRP. It is important to consider that Robor Tube uses only part of the normal MRP functionality, i.e. the explosion of required material quantities.

The MRP at Robor Tube generates quantity requirements for the following purchased items:

- Hot rolled Steel Coils of different thickness and material grade;
- Zinc for the purpose of galvanising;
- Sockets – for the coupling of conveyance pipes;
- Paint of different colors and qualities.

The MRP only generates quantity requirements for the manufacturing of steel strip. After scheduling the manufacturing requirements, the slitting operation cuts hot-rolled steel-coils into the applicable width for tube and pipe production.

4.7.5 FINITE SCHEDULING

Since Robor Tube operates in a fearsome business environment, it became apparent that survival on the medium and long term will depend on a few basic principals. Making money presently and in the future will depend on achieving shorter lead times, better due date performance, and keeping less inventory. All of this must be achieved under the assumption that throughput must increase, and operating expense must decrease or at least stay constant. The only way to stay competitive in a global economy is to increase Net Profit, Return on Assets and Cash Flow. Robor Tube decided to include finite scheduling as a priority in its new manufacturing systems. As discussed earlier, a hybrid MRPII-TOC model was identified as the ideal solution for the company.

Baan SCS Scheduler was chosen as the software tool to be integrated into the existing Baan MRPII manufacturing modules. Starting from a demand plan for the manufacturing environment, Scheduler sequences production orders precisely, taking into account order priorities and the finite availability of resources, in such a way as to maximise throughput and minimise cycle time. Scheduler creates a schedule not only based on the demand and material data from other planning systems, but also on current plant status data from plant floor systems. This seems to be consistent with the principle of the theory of constraints.

How does it work?

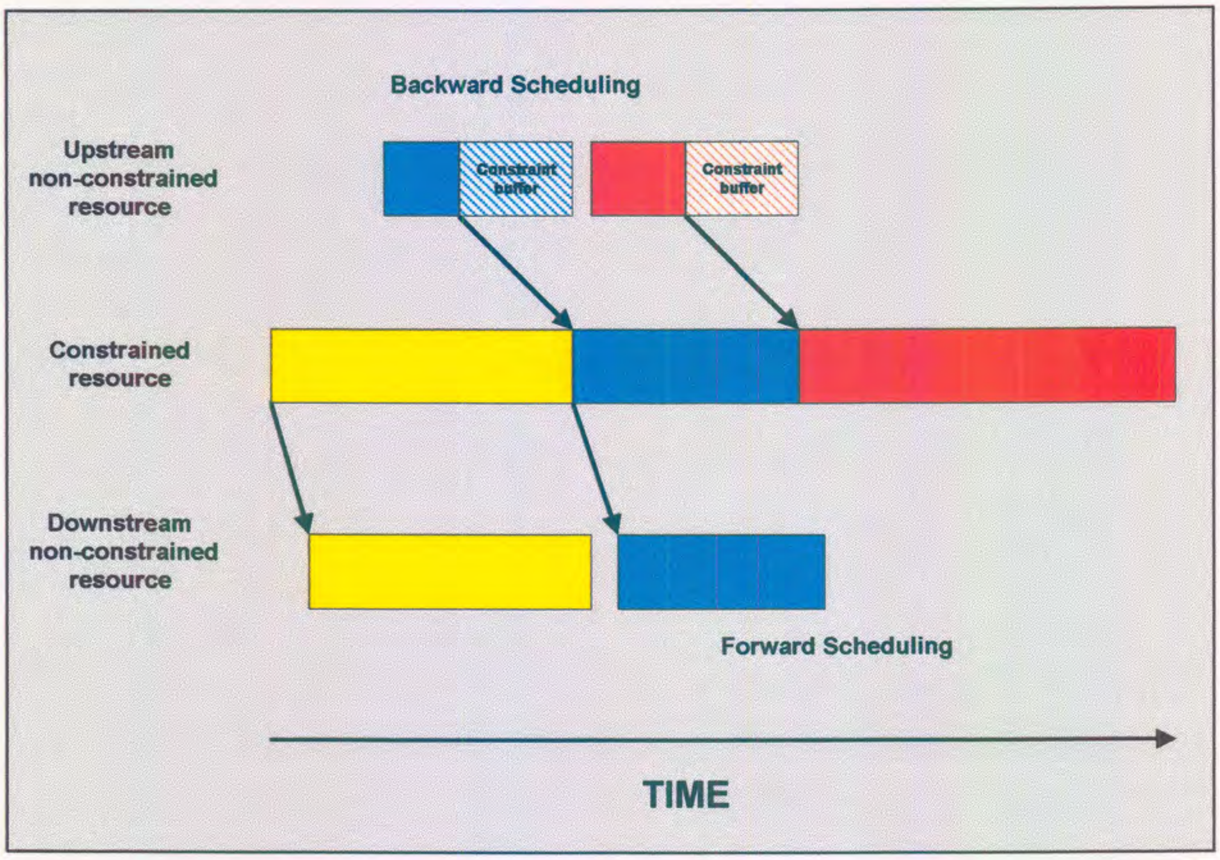
The Scheduler starts with a demand plan for manufactured products. This demand originates from the Master Production Schedule (MPS) and the exploded quantities calculated by the Material Requirements Planning (MRP) module of the Enterprise Resource Planner (ERP). This demand is then translated into a capacity demand for each work center on the shop floor. The demand for capacity is sequenced-based on the required due date for individual work orders. Based on the amount of capacity taken up on individual resources, a specific resource or resources are identified as being the constraint.

The identified constrained resource then acts as the drum that dictates the flow tempo through other work centers in the plant. Operations downstream from the constrained resource are forward-scheduled and thus follow the pace of the constrained resource. Operations up-stream from the constrained resource are scheduled backward to ensure that no material builds up in front of any non-constrained resource and to create a buffer in front of the constraint. This is consistent with the "rope and buffer" principle as defined by Goldratt in previous paragraphs. The diagram in **Figure 17** illustrates the principle as discussed.

In order to protect the performance of the bottleneck, the Scheduler makes use of dynamic buffers in front of the bottleneck. This is consistent with the "buffer" as defined by Goldratt in previous paragraphs.

Figure 17 indicates how the constraint determines the schedule.

Figure 17: Scheduling principles of the Baan Scheduler finite scheduling tool.



Baan Scheduler considers the following two factors in determining when the next or previous operation should be scheduled:

- ***Transfer Lot Size:*** This is the size of the lot that can be advanced to the next operation without disrupting the current operation. It is not necessarily the full batch quantity. The minimum transfer lot size is one unit, which implies that work on the next operation can start as soon as the current operation completed one unit. This functionality enables the Scheduler to schedule operations with an overlap; i.e. two operations can work on the same production order without considering the batch quantity.

- ***Transfer delay:*** This is the time necessary to move the completed transfer lot from the current operation to the next. It is dependent on the capacity of the material movement. It may be instantaneous in the case of a short conveyor, or as long as it takes to load and move a 16-ton trailer to the next operation.

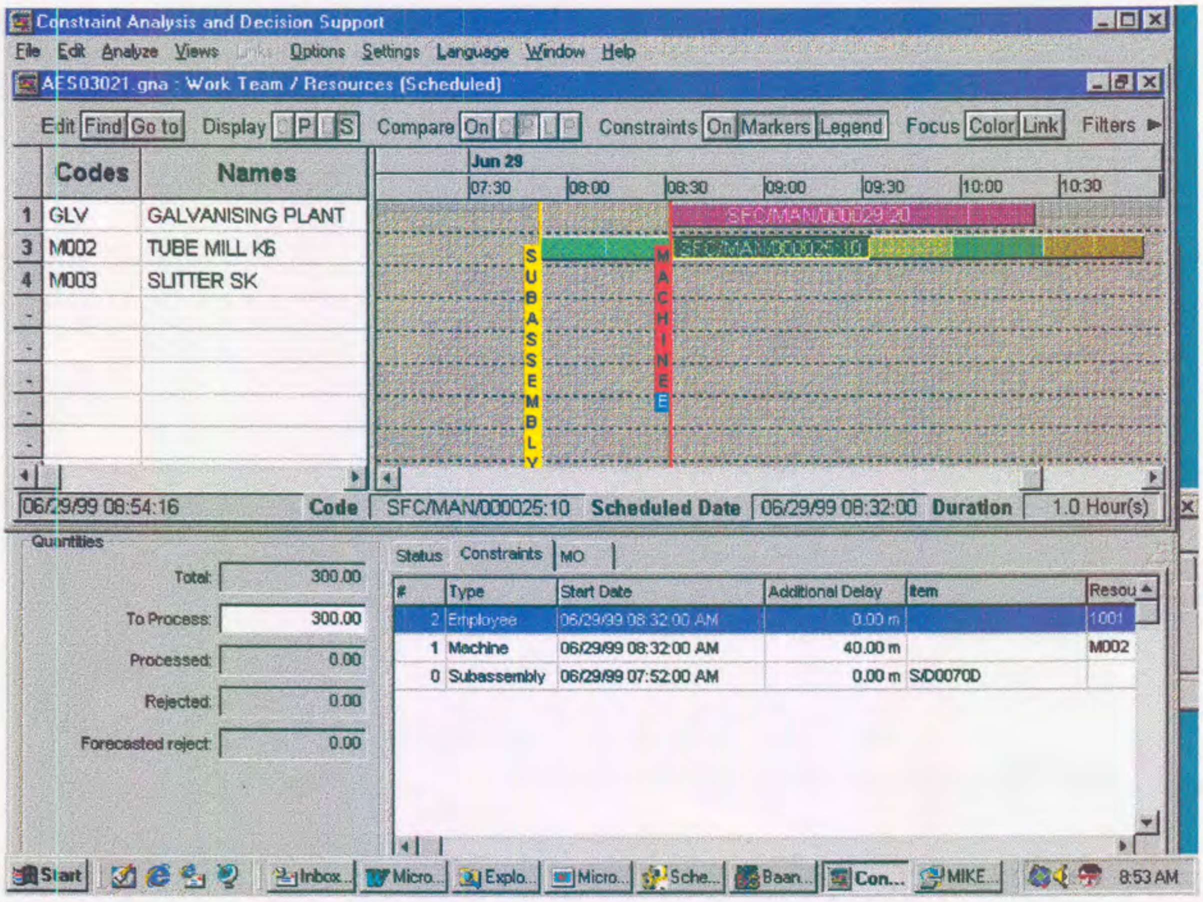
Scheduling machine capacity alone is however not sufficient to provide Robor Tube with a clear view of its ability to deliver. Production cannot start unless all material for a specific work order is available at the same moment as the people, machines and tools qualified to work on it. In order to create a feasible schedule, Baan Scheduler considers all the constraints in the manufacturing environment. These constraints include:

- Employees and their abilities, qualifications and work schedules;
- Equipment, with operating, maintenance and set-up times;
- Tools, and details about which people and equipment can use them;
- Materials-both raw materials and WIP (Work-in-Progress).

Scheduler considers the above-mentioned factors as well as the interdependencies between different resources to create a schedule for the shop floor. This ensures that the schedule is always feasible and practical. The schedule is presented in a Gant chart format to make it easy for the planner to follow the flow of orders through the manufacturing environment. **Figure 18** shows a display of a simple Gant chart in Baan SCS Scheduler.

Additional functionality enables the planner to manipulate the constraints by means of certain interventions. For example, if employees are identified as the constraint, the planner can manipulate their work schedules by means of overtime, and immediately see the effect on the throughput performance of the plant. If a specific tool is identified as the constraint, adding an additional tool can increase throughput. These are optimisation techniques to enable the planner to exploit and/or elevate the constraints in the manufacturing environment to its maximum.

Figure 18: A Gant chart showing scheduled operations for every work center. Constraints are indicated by means of coloured vertical bars.



It is important to note that the Scheduler will always produce a feasible schedule, because it considers constraints. The optimisation of the schedule, however, is a manual intervention by the planner. The techniques available in Baan Scheduler facilitate an iterative process to improve throughput, and due date performance. If confidence relating to the supply of products out of the manufacturing facility exist, the inventory policy can be adjusted to keep lower levels of finished goods.

The result of this is of course increased throughput and reduced inventory, without an increase in operating expense. The operations are then set according to the goal of making money, presently and in the future.

4.8 CONCLUSION

The aim of this discussion was to answer the question "What to change to?" The first step in answering this question was to identify the goal of Robor Tube. The goal was identified as follows:

To make money presently and in the future

Secondly, three global financial measures were identified to measure the achievement of the goal:

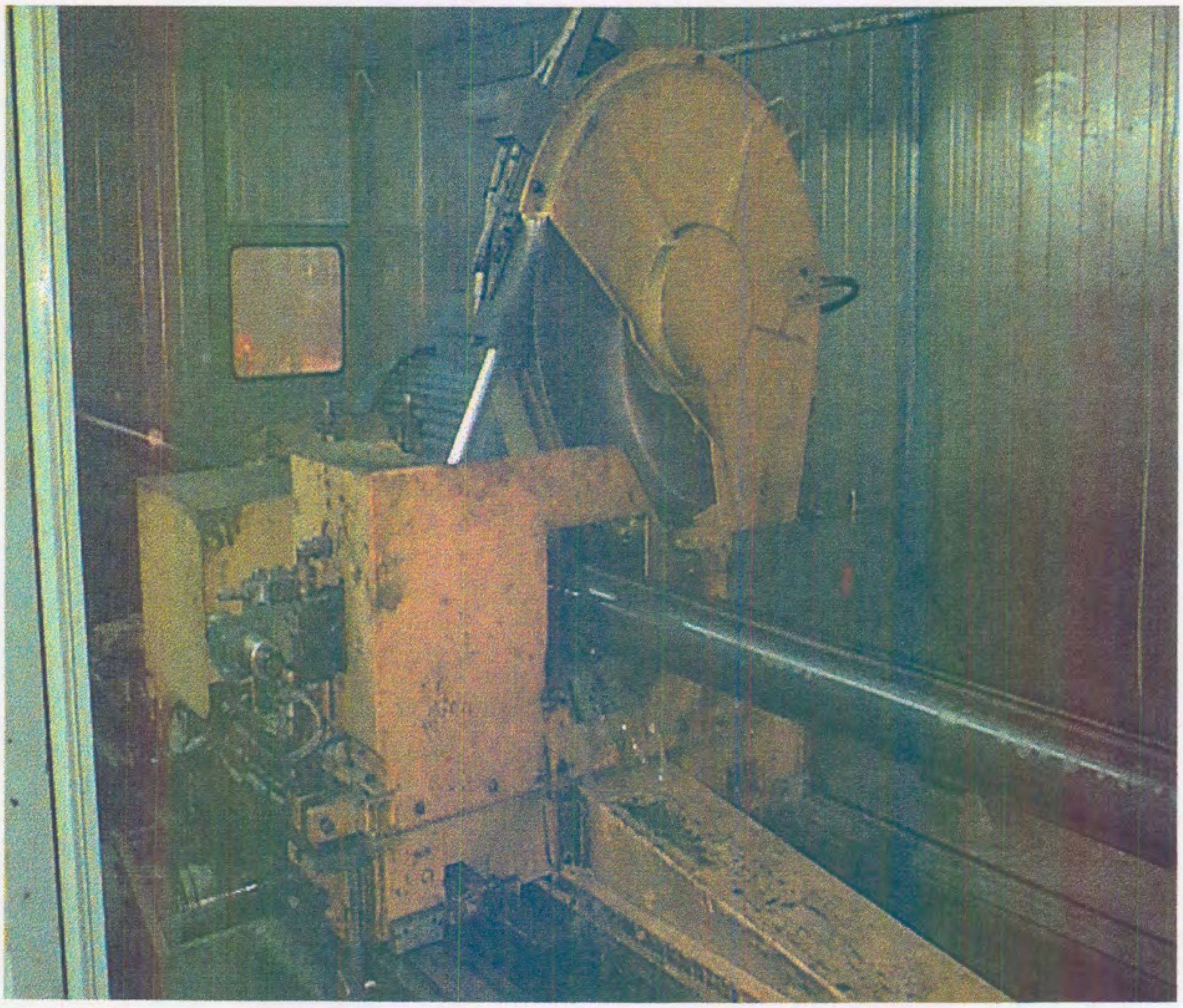
- Net Profit;
- Return on Investment;
- Cash Flow.

In order to improve the global financial measures, the following operational measures were identified:

- Throughput;
- Inventory;
- Operating expense.

Thirdly, it was decided to change the manufacturing planning and control system to a hybrid MRP-TOC system. The manufacturing module of Baan-ERP will be used as framework, but Theory of Constraints and the Drum-Buffer-Rope theory will form the basis of the manufacturing philosophy. Identifying constraints and scheduling accordingly will aim to minimise the variability in the supply of products out of the manufacturing facility, which will facilitate an improvement of the operational measures specified above.

5. How to cause the change?



5 HOW TO CAUSE THE CHANGE

5.1 INTRODUCTION

The first two questions in the discussion presented above were of a technical nature. The third question: "How to cause the change" is a psychological one. The processes and procedures developed within an organisation represent the culture of an organisation. Organisational culture is not formed overnight and can definitely not be changed overnight.

Forces that trigger the change process can be from internal as well as external forces. Internal forces may be subtle, such as low morale, or can manifest in outward signs, such as low productivity and conflict. Normally internal forces for change come from both human resource and managerial behavior/decisions (Kreitner & Kinicki 1995: 564).

External forces for change originate from outside the organisation. They normally come from the economic/market environment, the political environment and from the social environment or society in large. Market changes, like the emergence of a global economy, force organisations to change. From the brief discussion in the first section of this report, it is obvious that the change in the market for steel tube and pipe is significant enough to enforce change in this industry.

Robor Tube is no exception. The business environment changed significantly and the old and accepted way of doing things, will no longer secure survival and growth for the company. Like all other organisations, Robor Tube has its own culture that developed over a long time. Any form of change is therefore met with a varying level of mistrust and eventual resistance.

The following paragraphs will discuss issues regarding "resistance to change", and how Robor Tube chose to deal with it.

5.2 RESISTANCE TO CHANGE

No matter how technically or administratively perfect a proposed change may be, people make or break it. Kreitner and Kinicki (1995:570) states that resistance to change is an emotional/behavioural response to real or imagined threats to an established work routine. Goldratt (1990:10) agrees with this statement and summarise the process that connects improvements to emotional resistance in the following way:

Any improvement is a change
leading to
Any change is a perceived threat to security
leading to
Any threat to security gives rise to emotional resistance
leading to
Emotional resistance can only be overcome by a stronger emotion

It is important to note Goldratt's conclusion: *Emotional resistance can only be overcome by a stronger emotion.*

Before we consider possible strategies to overcome change, it is important to consider reasons for resistance. Kreitner and Kinicki (1995:571) state ten reasons why employees resist change. These reasons will be discussed with specific reference to Robor Tube.

- **The individual's predisposition toward change**

This is largely a consequence of the individual's upbringing and his/her personal background. The employees at Robor Tube come from an extremely diverse background (Italian, Greek, South African, Zulu, Sotho etc.). All of these employees' culture and background will cause them to behave differently and react differently to a changing environment.

- **Surprise and fear of the unknown**

A lack of proper information normally leaves change processes open to be portrayed as fearful and unknown. Informal communication like the "grapevine" caused anxiety in many employees at Robor Tube. Although the exact reason cannot be pinpointed, some employees left the company since the announcement and implementation of the new planning and production process.

- **Climate of mistrust**

Secrecy encourages mistrust and this can doom an otherwise well-conceived change. If there is trust in the decisions and actions of management, employees normally participate more openly. In the case of Robor Tube, openness and transparency of the change process limited mistrust to a minimum.

- **Fear of failure**

Self-doubt erodes self-confidence and cripples the development process. In Robor Tube, "computer illiteracy" caused a lot of fear. Some employees were intimidated by the new technology, because it was such a significant departure from the old manual process. Especially the older employees needed and still need extra encouragement in their own ability.

- **Loss of status/Job security**

The technological change of the new Baan-ERP system challenged the power bases that some employees held for so long. Previously planning and production employees had specialised knowledge which they controlled closely. This created "comfort-zones". Their anticipated power bases crumbled because of the intelligent recommendations of the new system.

- **Peer pressure**

Although a group of employees can negatively influence the decisions of the individual, it can also serve to positively affect the process of change. In Robor Tube, the latter happened. Pressure from peers caused mistrusting and negative employees to participate and buy in on the new concepts.

- **Disruption of cultural traditions and/or group relationship**

The changes in organisational structure that the new system implied, definitely had the ability to throw group dynamics into disarray. Employees that were previously responsible for production issues, had responsibilities added to their workload. From others, certain responsibilities were taken away because of the functionality and ability of the system.

- **Personality conflicts**

Robor Tube experienced the case where some of the senior managers clashed with some of implementers of the system. This of course caused some resistance toward the outcomes of the new Baan ERP-TOC system. In retrospect, conflicting personalities caused the disruption. Some of the employees actually admitted that their personalities were responsible for some of the conflict.

- **Poor timing**

An organisation must be ready for change before it can be effective. Changes introduced in an insensitive manner and at an awkward time, can cause undue resistance. In that regard, Robor Tube had something to consider. A multitude of changes was introduced in recent times. Employees were bombarded with new concepts and procedures. The climate was and still is not entirely conducive to the fundamental changes proposed in the previous sections. The market forces are however so strong, that delay could imply failure in the market place. The imperative therefore was to push forward although the company was not entirely ready.

5.3 STRATEGIES FOR OVERCOMING RESISTANCE TO CHANGE

Smith (1994:6) identifies management education as the key to implementing TOC under MRPII. Kreitner and Kinicki (1995:574) extend this concept to include all levels of employees and urge communication with employees throughout the process of change. They advise managers to include the following in a process of change:

- Provide as much information as possible;
- Provide reasons/rationale for the change;
- Conduct sessions to answer the questions of employees;
- Discuss how the changes will affect employees.

Smith (1994:6) states that there is a need for education throughout a company and a change in overall management philosophy. He advocates a layered approach where a specific level of the organisation plans the implementation of change for one level below them. He states that this process should continue down the organisational level until a level is reached where people no longer resent being led.

Smith (1994:6) warns that each step in the change process must not cause any resistance in other groups within the organisation, since that will jeopardize the implementation of change in the levels below. Goldratt (1990:11) states that emotional resistance can only be conquered by stronger emotion, and suggests the emotion-of-idea ownership by inducing people to invent the idea themselves, through the Socratic method, using leading questions.

Considering the theories above, three central themes emerge:

- Education;
- Participation;
- Communication.

Robor Tube considered these three factors to be central to the implementation of an MRPII-TOC-based manufacturing planning and control system.

5.4 THE IMPLEMENTATION PROCESS

5.4.1 APPROACH

Robor Tube decided to use an approach where knowledge and ability is transferred from one level of the company to the next. This approach will form an effective way of ensuring that the system meets the requirements of all levels in the company, and that ownership is transferred as speedily as possible. Three groups of employees was identified to play a vital role during the implementation:

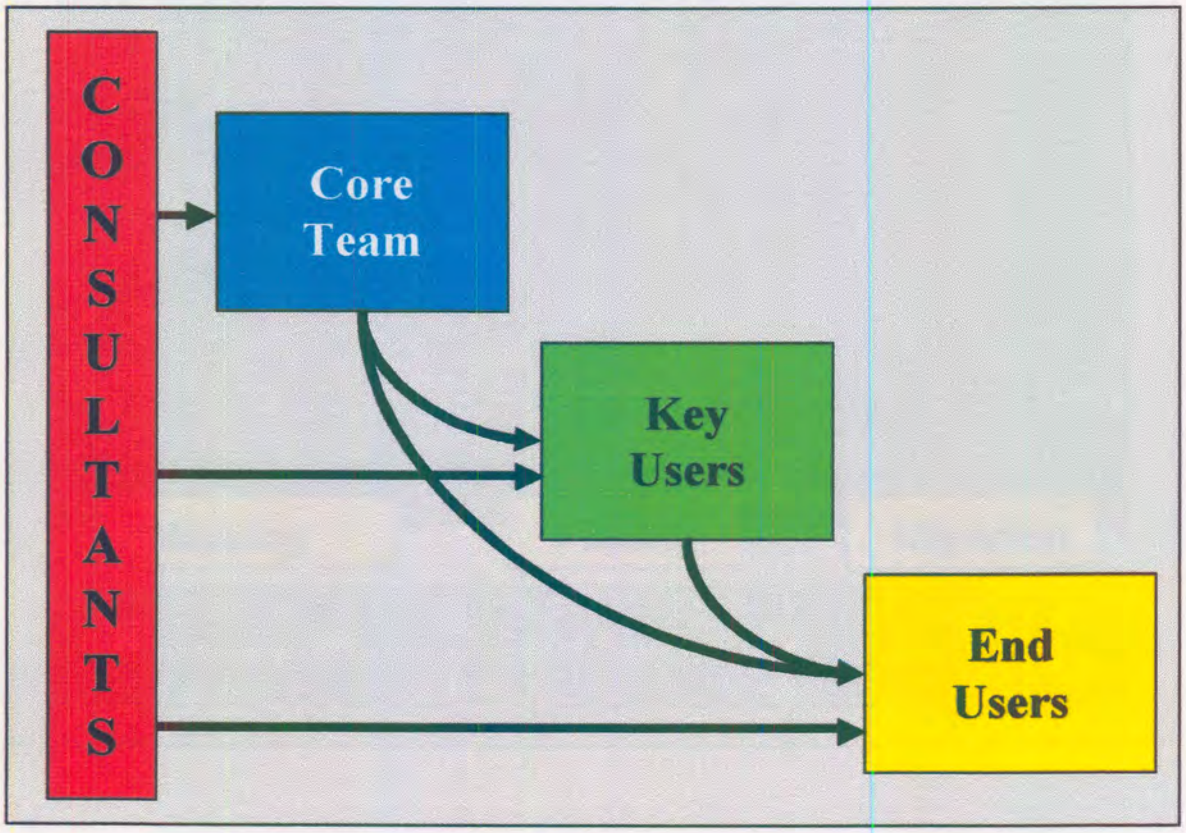
- ***Core Team:***
  This Team consisted of a small number of fully dedicated employees representing various disciplines within the company. They were tasked with the primary aim of implementing the system within the company and to resolve any business, technical or cultural constraint that might negatively influence the success of the implementation.

- ***Key Users:***
  The Key Users were responsible for the implementation of the system within a particular functional area. They were tasked with managing the functional levels within the company and promoting the implementation internally. The Key Users had the ability to create and evaluate a model of the business. They had the ability and authority to address problems relating to organisational, functional and technical bottlenecks.

- ***End Users:***
  The End Users had the responsibility of performing the operational tasks necessary to run the system once it has been implemented. They had to support the Key Users in taking content related decisions when required.

The basis of this approach was that knowledge and ability were transferred from the Core Team to the Key Users and from the Key Users to the End-Users. The effect of this approach was that knowledge and ability rolled down through all the levels of the company. During this roll-down, functionality and principles were evaluated and improved before passed on to the next level. **Figure 19** indicates how knowledge was transferred from one level to the next.

Figure 19: Knowledge Transfer through three organisational levels.



The advantages of this approach were the following:

- The approach facilitated participation from all levels in the organisation;
- All organisational levels evaluated the models defined by the Core Team;
- Ownership was effectively transferred from the Core Team to the Key- and End Users;
- The Knowledge Base was broadened throughout the organisation.

5.4.2 IMPLEMENTATION PHASES

The implementation of a TOC-based manufacturing planning and control system for Robor Tube, was divided into three distinct project phases, namely the Mapping Phase, Piloting Phase and a Migration Phase. The main activities during each of the phases were the following:

- ***Mapping Phase:***

  This project phase consisted of reviewing the software configuration versus business processes and configuring the system to serve the required processes. The definition of objectives, rough-cut plans, implementation, organisation and reporting dominated the early stages. The main activity, however, was to design an overall conceptual model of the business.

- ***Piloting Phase:***

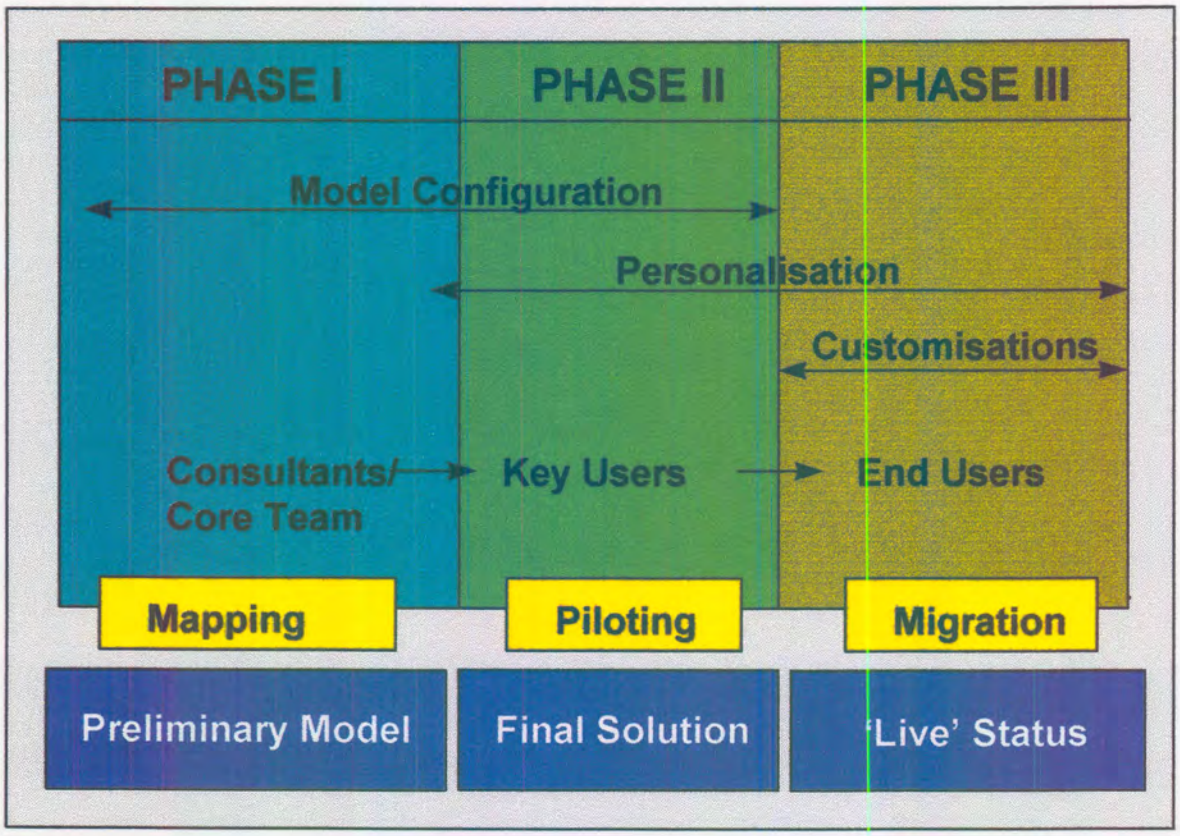
  The Key Users were trained on the functions and inter-relationships between the application software and the business processes. The conceptual model from the previous phase was evaluated and amended during workshops with Key- and End Users. Master data requirements, i.e. Bills of Materials and routings, were prepared and system customisations were defined. Customisations include management reports and operational documentation needed to run the shop floor environment.

- ***Migration Phase:***

  This stage was focussed on the preparation of the new system and the transfer from old to new. End users were trained and procedures drafted. After the system has been configured as defined in the previous phases, a "test mode" was made available to end users for final testing.

The completion of the migration phase acted as a trigger to start using the functionality thereof in a live environment. The process continues as the system is continuously improved to serve the needs of users and management alike.

Figure 20: The implementation phases used by Robor Tube.



5.5 CONCLUSION

In the theoretical discussion above, Robor Tube identified three critical success factors in the implementation of a TOC-based manufacturing planning and control system:

- Education;
- Participation;
- Communication.

The approach as described in the previous discussion, had the effect of knowledge filtering down through the levels of the organisation. Education and training were kept as practical as possible. A superior, with the help of the Core Team, had the responsibility of training his subordinates. This approach forced the superior firstly to ensure his own knowledge and ability before attempting to train his subordinates. The approach had a far greater impact than formal "classroom" type education. It also created an environment of trust and acceptance. Because the computer literacy of especially the operational levels left much to be desired, the joint learning with colleagues facilitated group cohesion, which led to less fear of the unknown and of failure.

The implementation process was divided into three distinct phases. In the first phase, the Core Team presented a preliminary model of the business. The model was subjected to the critique and comments of the Key Users before progressing to the next phase. Similarly, the Key Users had to finalise the business model, and address the concerns of both the lower and higher levels before the implementation could progress to the live environment. Throughout all three phases, employees from all levels participated in the design and configuration of the new manufacturing system, resulting in openness and transparency that made the change within the manufacturing environment more bearable.

Especially during the initial phase of the implementation, great emphasis was placed on communication to address the fears and concerns within the manufacturing environment. During special feedback sessions, the rationale and reasons for the changes were communicated to the operational level of the organisation. These sessions facilitated communication between the different functions and levels within the manufacturing environment.

Addressing the fundamental issues of education, participation and communication, created an environment suitable for the changes to proceed without major disruption. Once the benefits to the organisation and individuals became known, the change process could be implemented without major resistance.

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6. Conclusion

6 CONCLUSION

Robor Tube is the leading manufacturer and distributor of steel tube and pipe in South Africa. The company operates in an extremely competitive market that causes extreme pressures on profitability on all participants in the market. Although the company was profitable for many years, it was suddenly confronted with extreme financial pressures.

During 1997, management decided on an initiative to upgrade systems throughout the company. Baan IV was chosen as the Enterprise Resource Planner to serve as the backbone for company information. Initially the Finance, Sales and Distribution models were implemented during 1997. Manufacturing Planning and Control System was left for a later implementation.

During 1999, high inventory levels and poor due-date performance forced management to task a project team with the implementation of a manufacturing planning and control system for Robor Tube. The aim of the implementation was the following:

- To improve the profitability of the company over the short and long term;
- To improve customer service by means of reliable , on time delivery;
- To improve the responsiveness of the company to rapidly changing market conditions.

Firstly, the company considered the aim carefully and after a detailed study of the operations within the manufacturing environment identified the following factors to be changed:

- The policy of governing inventory in Robor Tube, needs to be revisited;
- The methods used for scheduling need to be refined;
- The goal needs to be defined and new measurements derived.

Secondly, after considering the factors above Robor Tube had to answer the question "What to change to?" In other words, the company had to identify the solutions that will address the factors identified in the previous paragraph. The following solutions were identified:

- The goal of the company was identified to be making money now and in the future. The operational measures to support the company goal were identified to be throughput, inventory and operating expense.
- The manufacturing planning and control system was to be based on a hybrid MRP-TOC model. The manufacturing module of Baan-ERP will be used as a framework and the Theory of Constraints and the Drum-Buffer-Rope theory will form the basis of the manufacturing philosophy.

Thirdly, the company had to answer the question "How to cause the change?" or in other words, how to make the identified solutions happen. Robor Tube identified three critical success factors in the implementation of the identified solution:

- Education;
- Participation;
- Communication.

The company followed a phased implementation methodology where knowledge and ability was filtered throughout all levels of the organisation using a "top-down" approach. The process created an environment suitable for change and once the benefits to the company and the individuals concerned became known, the solutions were implemented without major resistance.

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