PRODUCTION PLANNING AND PRODUCTIVITY METHODS FOR A MOLDING MANUFACTURING FACILITY

by

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Abstract

This thesis focuses on production planning and productivity improvement efforts for a molding operation. The goal of these efforts is to reduce variation in quality measurement and control at its facilities and increase capacity. The facilities that are a part of the molding division are experiencing material shortages, seasonality in demand, and capacity shortages. Data collection and measurement inconsistencies provide an additional challenge. The limited testing of raw material inputs adds to process variation. Quality improvement efforts, production system yield model and production planning model are three strategic tools used to address the issues facing the facilities.

Quality improvement efforts include increasing incoming inspection of raw materials, improving measurement of material losses through the process, and establishing the appropriate measures and procedures to determine and eliminate root cause of material loss. Concentrating on improved product quality will reduce customer returns, provide raw material savings, and increase capacity through productivity gains. As the product receives more processing and increases in value, the cost implications of scrapping it increase.

The production system yield model, a facility asset utilization model, was applied to several facilities. This model calculates an efficiency metric for each facility based on five parameters: Rate of Quality Products, Run Speed Efficiency, Scheduled Time, Net Production Rate, and Molder Run Hours. This model is a tool for management to determine where to focus improvement efforts and to assist in standardizing production measures at various facilities.

The purposes of the production planning model are to assist management in making decisions about the business unit on a regional level, and in establishing a stronger communication link with all functions of the organization. The production planning model is a spreadsheet tool that incorporates information from the Production System Yield model to establish demonstrated capacity and to analyze the ability to meet various demand scenarios. A key finding was that a 67 percent decrease in internal process scrap was shown to increase regional capacity five percent. For effective use and implementation of the production planning model, production system yield model and quality improvement efforts the following is recommended: increasing transfer of manufacturing operating knowledge between facilities, determining appropriate levels of excess demonstrated capacity and levels of product inventory, and improving forecasting tools and techniques.

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Chapter 1: Introduction

1.1 Company Background

This thesis focuses on production planning and productivity improvement efforts for a molding operation. The molding operation is part of a division of a diversified multinational corporation. The molding division has numerous facilities manufacturing similar products on machines at various locations globally. Some facilities are small operations with a handful of machines while others are much larger and operate numerous machines. In addition, a group within the division is an original equipment manufacturer of the machinery that produces the product. Some of their competitors buy equipment from them, while other competitors purchase an alternative technology. Research and development, product design, and other support functions are located at headquarters. Depending on regional markets, the intensity of competition and number of competitors vary. Product mix varies depending on facility. Also, customer order quantity varies at locations, with some locations having a higher product mix with many smaller orders. The division has a large market share domestically, as well as in certain global markets. All of the facilities combined produce billions of a similar product per year and this is on the same scale as pill, disposable cup or paper clip production. Facilities are often regionally located close to the customer to reduce shipping costs. In some markets, the product is a commodity, while in others it is a specialty product. The product is generic in size, but style, color, and appearance can change based on customer requirements.

In the past the strategy for manufacturing has been "make to order", but due to the need to increase facility asset utilization, it is becoming "make to stock." All facilities have a degree of seasonality for the products they produce. As the demand for the product increases, in all of the markets they compete in, the level of competition is increasing. The division is rapidly expanding internationally to better serve the increased demand, as well as to better serve customers requiring in-country manufacture. To maintain high utilization of capacity and ensure that orders are met, when possible or necessary, facilities will support each other with product. Price and quality have increasingly been issues. Certain customers are requiring shorter lead times between order placement and product delivery. Due to the increased competitive environment, cost, quality, increased productivity, and capacity are critical issues. Material costs are rapidly increasing due to tight supply. Presently, the division relies on multiple suppliers of raw materials.

1.1.1 Manufacturing Process Flow

The process has three basic steps, as shown in Figure 1-1. In the first step, polymer is extruded and molded into the product design shape. The rate limiting step in the process varies, depending on equipment layout. Inspection of molded product is performed by operators at regular time intervals to ensure the product has the correct dimensions and meets specifications. There are numerous reasons why product could be scrapped and these include machine startups, color changes, off-color product, other visual defects, mechanical defects, incorrect dimensions, and process adjustment, etc.. Blocks of extruded polymer that are not molded into product shape, polymer purge, are sold. Generally, the amount of polymer purge is small in comparison to scrapped product and may occur during startup or when a process upset occurs. Product that is scrapped after the first step can be reground and the polymer can be reused in the process. During the later steps of the process polymer cannot be recycled. Depending on the product and customer specification, an off-line step may need to be performed or Step 2 and/or Step 3 may not be needed.

In Step 2, Post Mold Processing, additional functional requirements of the product are added, and the product is modified to meet customer specification. A customer specified and approved material, such as a customer approved polymer, will be incorporated into the product. Customer approved polymer purge and scrapped product(molded unit with or without customer approved polymer) are both sold. Product can be scrapped for the same reasons as in molding. In addition to operator inspection, on-line and off-line product inspection machines evaluate product for defects.

In Step 3, final finishing of the product is done, but no additional mechanical modification is performed. This final step includes labeling and packaging the product. The operators inspect the product at regular time intervals. Product scrap reasons are similar to those mentioned earlier. After the product is packed into a box it is sent to the warehouse and shipped to the customer.

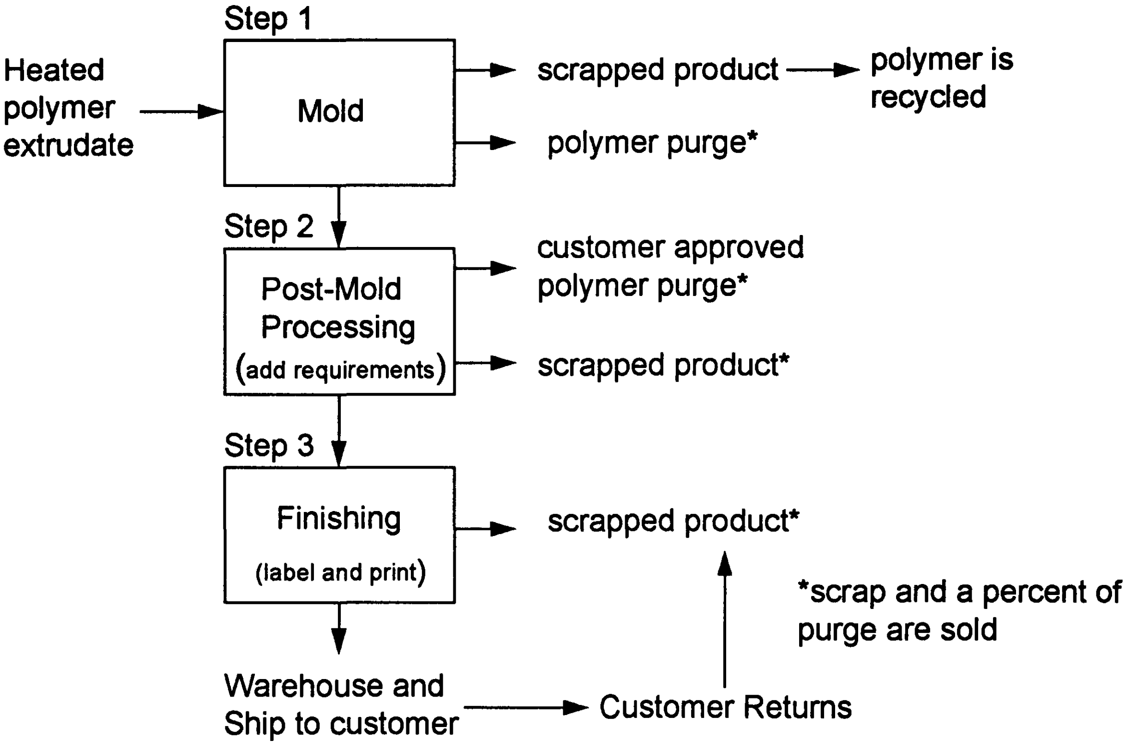

Figure 1-1: The production process is designed for molding to be the bottleneck. During each step inspection determines if product contains defects. Scrapped product at the molding step is recycled and reused in the process while other scrap is sold.

1.2 Highlights of Research

The need for standardization and control as well as the present state of material and quality management within the division lead to the thesis focus. The major topics of the thesis are material and quality systems, measurement control and the benefits of production planning at a regional aggregate level. The remainder of this chapter explains the motivation for the thesis. In Chapter 2, an initial framework for addressing quality, measurement control and the linkage between scrap, speed and capacity as it relates to production planning is outlined. The need to define quality is discussed as well as how quality can positively impact activities within the organization. In Chapter 3, a measurement control model, Production System Yield, is explained and the benefits and limitations of the model are examined. In Chapter 4, Production Planning expands on the work of Chapter 3 and discusses capacity losses and their implications on manufacturing and material requirements. Chapter 5 re emphasizes the benefits of quality measurement processes and control and some of the key learnings.

1.3 Motivation For Research

As the business unit has grown in size many issues have arisen. Figure 1-2 shows several major reasons why meeting customer orders has become an increasingly difficult task. As the division begins to grow, linking demand forecast, production planning, productivity and materials requirements become essential. Raw material shortages in 1994 and 1995 and limited capacity are major issues facing most locations. Planning production levels is a challenge, since marketing could be off as much as 20 percent on forecasted demand. Marketing states that the customers do not have a good feel for what their demand is and this makes it difficult to determine. In the past, the strategy of manufacturing has been make to order, but as demand increases beyond capacity in peak months it is difficult to maintain this focus without adding capacity. To counteract the seasonality of the business, inventory leveling is being attempted. However, excess capacity targets to provide flexibility and inventory targets have not been firmly established. Product mix, tool shortages, and product changeovers are major scheduling issues. Also, an effort to standardize manufacturing performance measures is beginning since information is required on issues such as downtime, scrap rates, and promised performance.

The organization has a very lean management structure. Being geographically spread out increases the challenges of managing the business. The rapid growth and expansion has created a reactionary environment where individuals are responding to day-to-day crises. Therefore, a limited number of people are involved in planning, competitive benchmarking, and sharing of knowledge between facilities. New customers are being acquired, but not as quickly as they could be in specific markets since there is not enough capacity to meet demand. In certain markets the facilities do not have space to add new machines and the market is mature, therefore, the business unit does not want to add additional capital. These more mature facilities are supporting demand in emerging markets while plants are completed and expanded to support local demand. Resources at the mature facilities are also being assigned to assist in plant start ups. Expansion has not slowed, so the problem of mature markets supporting new markets will continue.

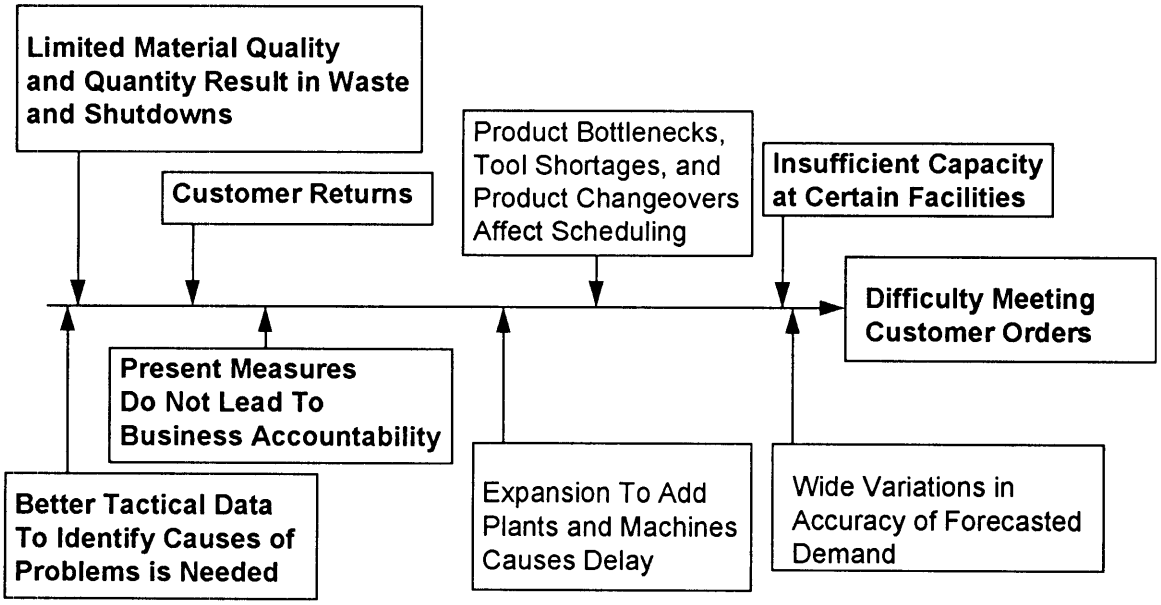

Figure 1-2: There are several reasons why meeting customer orders is a challenge, and the boldface issues will be discussed in more detail.

1.3.1 Measurement Of Process

The facilities collect a large amount of data. Data collection measures were implemented because the information may be helpful in the future. When a new measurement system was created, the old system was not modified or eliminated, since certain individuals still use the old system. There is no agreement or standard on one measurement system. Also, the data that is recorded does not always reveal the root cause of problems. When an equipment failure occurs and results in the shutdown of a machine there may be several options for the operator to record downtime for the same failure. For the first step in the process there are 100 downtime codes for why a molding machine that is scheduled to run is not operating. Facilities also have the ability to customize and add their own codes. Oftentimes, there is no agreement on downtime definitions by data collectors and all users of the data. Therefore, data accuracy is not consistent and becomes questionable when making decisions. Also, the structure for people to be accountable for their data is not in place. When a facility runs out of material unexpectedly it is not always clear who is responsible for ensuring the situation is resolved.

1.3.2 Raw Material

There is a limited amount of raw material available to make the product. Increased demand for polymer, natural disasters that have closed down polymer facilities, and the delay of new plants producing the polymer all have contributed to creating a worldwide shortage. Some suppliers will not guarantee that they can provide material. One supplier has an exclusive contract with the competition. Also, the price of polymer is rapidly increasing, escalating manufacturing costs. Although increases in the price of the product have been announced, these increases have not kept up with the escalating material costs to the facilities, and the customers have not always agreed to the increased price. One facility shut down for several days since they could not get additional shipments of polymer material. If a facility has 10 molding machines, shutting down one molding machine for a day results in a ten percent average daily revenue loss. Based on facility size, shutdowns due to material shortages can be extremely costly. Although some recycling of material is done after the first process step, not all of the facilities are committed to doing it. One facility has the equipment in place to recycle material, but over time, recycling was stopped. Assuming that this one facility could recycle 70 percent of scrapped material after the first process over an eight month period it could have saved approximately one percent of material costs(this number is based on material cost during the seven month period, and material costs have increased 20 percent since then).

There is limited or no quality inspection of incoming material. Raw material suppliers are certified to ensure that material specifications can be met. The philosophy of the facilities has been to trust the suppliers to test material in their performance laboratories. Additional testing equipment and training are considered to be too costly. Also, labor would need to be trained to do these tests. There are some questions regarding the appropriate tests to perform, since correlations on which material properties will result in product defects or increased process waste are not well defined. One facility does a melt flow index as their check and it had rejected four percent of shipments in 1994 as shown in Figure 1-3. Melt flow is a measure of polymer molecular weight or chain length, reported in grams. The target melt flow is X grams and the upper and lower specifications are 1.18X grams and 0.82X grams respectively. The suppliers and facilities melt flow measures cover the whole specification range during the given time period. Figure 1-4 shows that this facility has not rejected material in 1995, but the variation in melt flow is considerable. Other facilities do not do this test, so there is no basis for them to reject incoming raw material shipments.

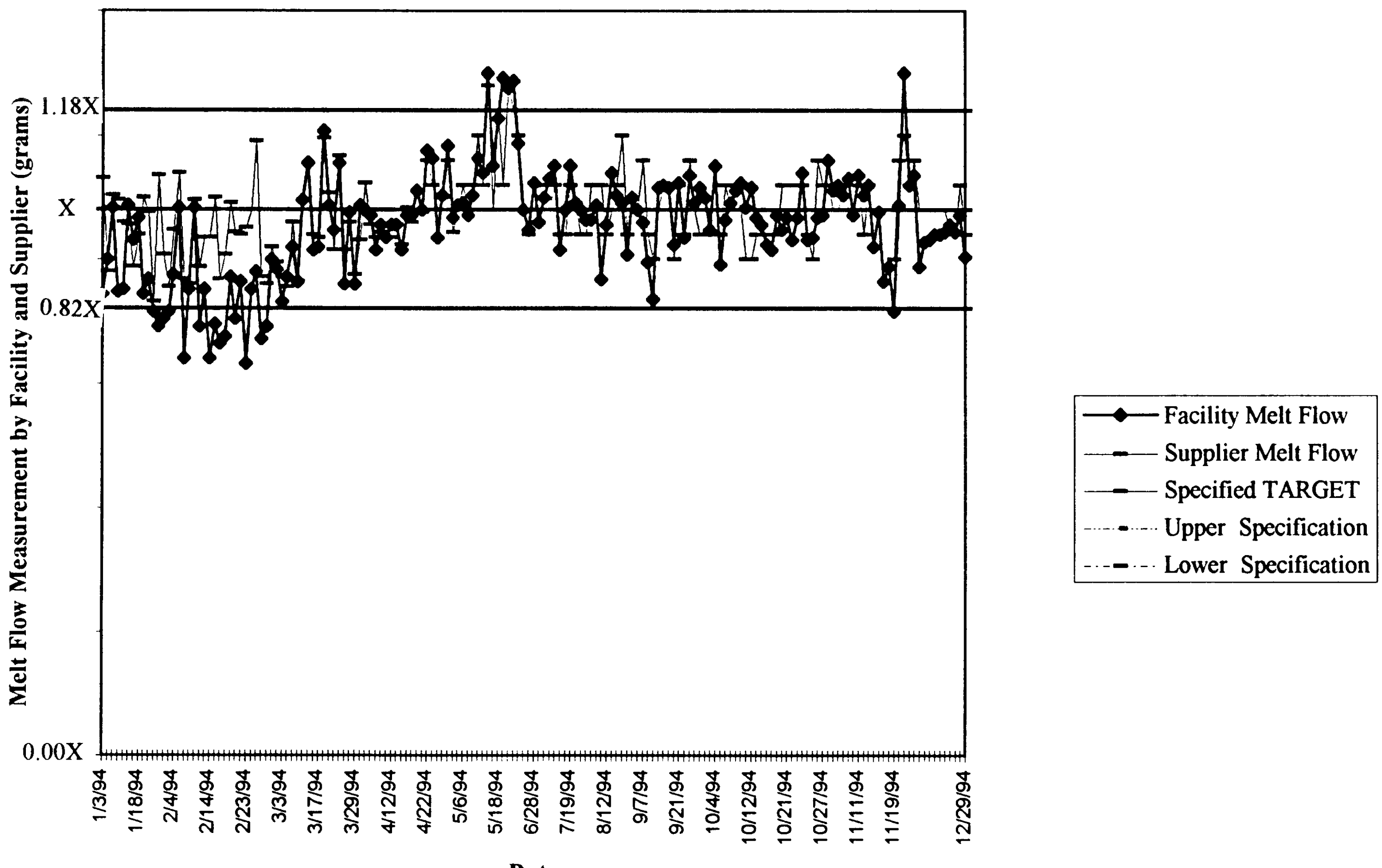

Figure 1-3: Comparing Facility 1 and Supplier Melt Flow Reveals Wide Variability and 4% of shipments are out of specification.

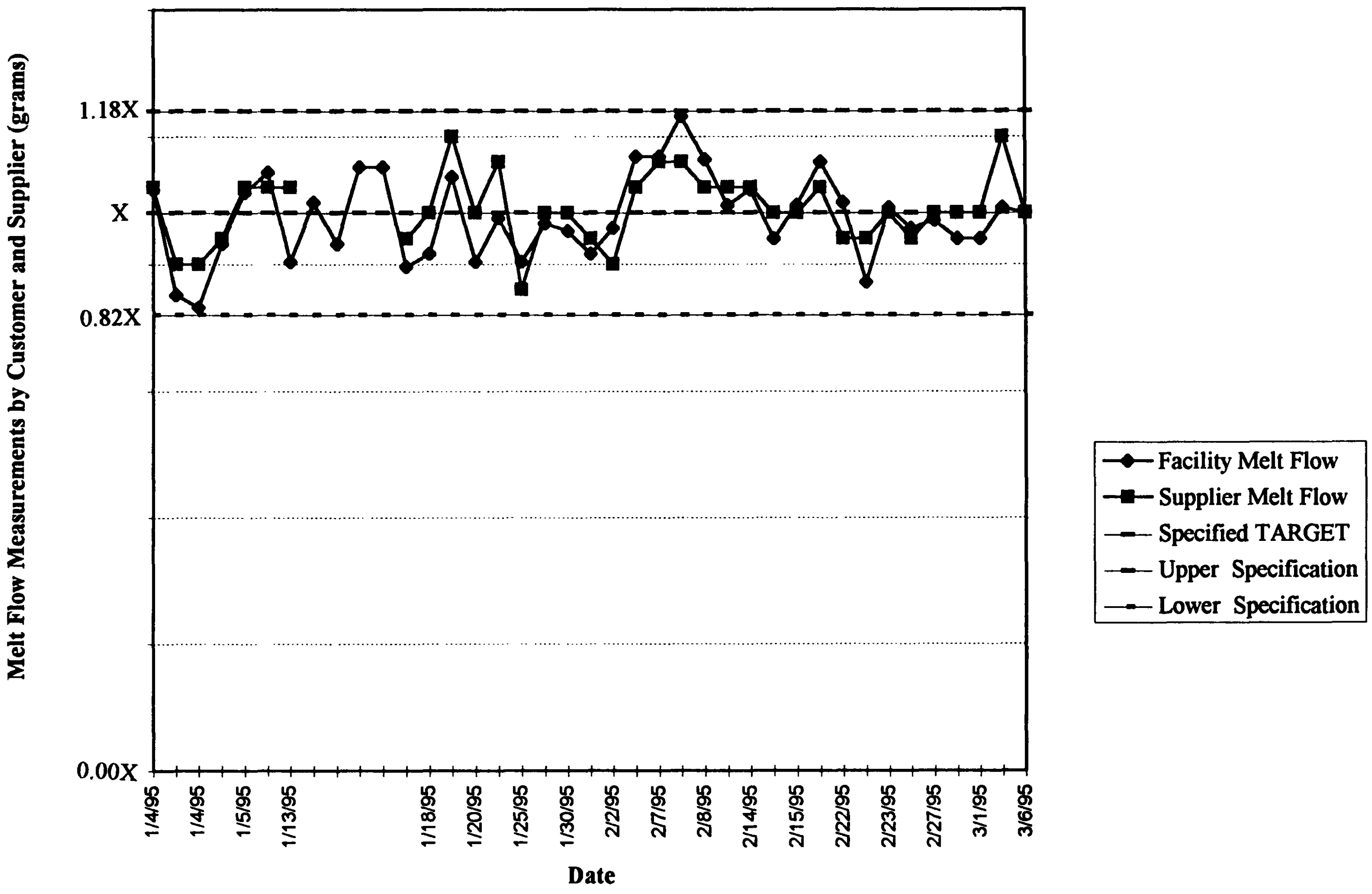

Figure 1-4: No polymer shipments have been rejected, but there are large variations in melt flow.

1.3.3 Scrap Rates

In Figure 1-1 the various types of scrap that are measured are given. The definition of scrap varies and all definitions have some component of estimation in them. Reported Total Process Scrap is the daily scrap occurring during these three steps which direct labor identifies, estimates and records as having been generated. Estimation techniques involve direct labor visually determining how full a given container of scrap is and converting this value to number of units scrapped. A gap between reported and calculated scrap rates exists, and Figure 1-5 illustrates this gap over a ten month period. For the ten month period, if calculated scrap was X percent, reported scrap was 0.3X percent. Part of direct labor's performance evaluation is tied to individual scrap rates, and is one possible indicator of why reported scrap rates are lower than calculated. Calculated Total Process Scrap is a measure used in the Production System Yield model; the latter is defined in detail in Chapter 3. Calculated total process scrap is a measure of scrap between the mold process and completion of finishing process. There is an actual count of the product at the Finishing step that is boxed and ready for shipment (packed), but the amount of product molded is often estimated, which may cause some error in the calculated scrap number. The definition of calculated total process scrap is one minus the quantity of product packed divided by total product molded.

Since the calculated total process scrap measure relies on estimation, a check of the assumptions suggests that this number overstates the scrap levels. Given the reported total molded number, machine speeds can be back calculated. Operators record machine speeds(this includes molder speeds) once a day and they are generally constant, with minor fluctuations. The total product molded measure should approximately equal the reported molding machine speed multiplied by molding machine run hours. Molding machine run hours are recorded by the operator from the machine controller (electronic control system that operator resets at given intervals). Molding machines would have to operate between four to five percent faster than reported for the calculated total scrap measure to be valid. Assuming the reported molder speed is correct, and using molding machine run hours, a revised number for scrap, the Estimated Total Scrap Rate, can be determined. This estimated scrap rate is 0.6X percent for the ten months (versus X percent for calculated scrap) and this number is between reported and calculated. The estimated scrap rate is one minus the quantity packed divided by the quantity molding machine run hours multiplied by reported molder run speed. Although there is potential for machine run hours to be understated, it is a more accurate number to use to calculate total product molded than using a total molded number based on visual estimation. If estimated total scrap rate is assumed to be the actual scrap rate, then approximately six percent in potential revenue was foregone at Facility 1. Another way to state this is that producing this level of scrap during the given ten month period is the same as having two machines unable to operate for eight months.

Material usage is important to other functions within the organization outside of manufacturing. The finance department keeps track of how much material was used for the month based on silo inventory and compares this to the amount of quality product produced and Reported Total Process Scrap Rates. A variance suggests that there is a discrepancy between the amount of material used in the process and the amount of material purchased for use. During a ten month period Facility 1 was able to account for 98 percent of purchased material that entered the process, with 97 percent ending up as shipped product, and one percent ending up as reported scrap. At Facility 1, two percent of material that entered the process could not be accounted for. Some information on material usage is not recorded, since there is no process or procedure in place to capture this information. An example is that research and development performs designed experiments on production equipment, and may or may not use their own materials. Generally, it is assumed that information that is not recorded is a small fraction of the overall material used.

Month	**Calculated Total Process Scrap**	**Reported Total Process Scrap**	**Estimated Total Process Scrap**
January	**X_1%**	**0.33 X_1%**	**0.59 X_1%**
February	**X_2%**	**0.41 X_2%**	**0.67 X_2%**
March	**X_3%**	**0.34 X_3%**	**0.63 X_3%**
April	**X_4%**	**0.34 X_4%**	**0.68 X_4%**
May	**X_5%**	**0.28 X_5%**	**0.63 X_5%**
June	**X_6%**	**0.23 X_6%**	**0.56 X_6%**
July	**X_7%**	**0.23 X_7%**	**0.47 X_7%**
August	**X_8%**	**0.23 X_8%**	**0.60 X_8%**
September	**X_9%**	**0.24 X_9%**	**0.58 X_9%**
October	**X_{10}%**	**0.20 X_{10}%**	**0.46 X_{10}%**
Year to Date 1994	**X%**	**0.3 X %**	**0.6 X %**

CALCULATED = 1 - (PACKED/TOTAL MOLDED)
REPORTED = VISUAL ESTIMATION BY OPERATOR
ESTIMATED = 1 - (PACKED/(RUN HRS. x “REPORTED” MOLDER SPEED))

Figure 1-5: Due to estimation techniques it is difficult to determine the exact scrap rate.

Customer returns are also a part of scrap. At a minimum, when a customer returns product, a partial or full product price credit is given, depending on the reason for the return. Over an eight month period of time Facility 1 had 0.2 percent of product shipments result in returns and Facility 2 had 1.3 percent of product shipments result in returns. After the product goes through the finishing process, no additional value is added to it but shipping product to the customer does add cost. Figure 1-6 show the major cost steps and the value added steps that the product undergoes prior to leaving the facility. The value added steps are during product processing. An additional cost that is not shown is inspection cost incurred after each manufacturing step. There are more cost steps in the process than value added steps.

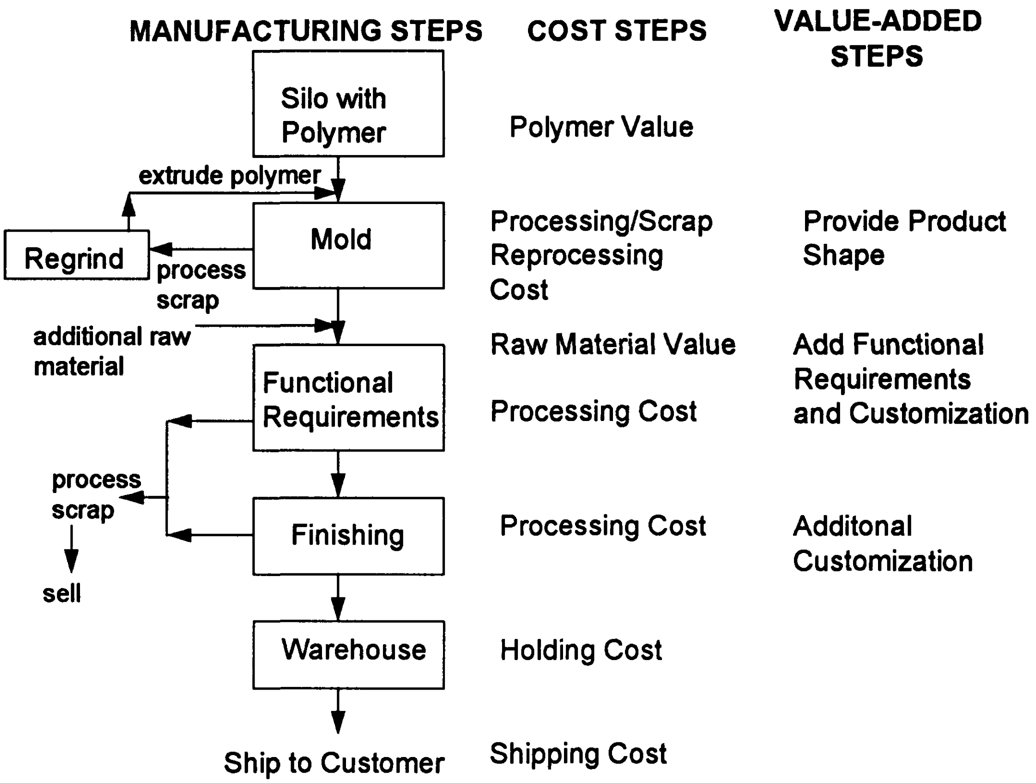

Figure 1-6: Manufacturing cost and value added steps related to manufacturing process.

Chapter 2: Method For Improvement

A framework for addressing the issues facing the facilities will provide a systems approach to working toward improvement. Included in this framework is an increased quality focus, a measurement control plan emphasizing the reduction of disruptions and variations in manufacturing, and an understanding of linkages between variables that will increase capacity and throughput. Quality and quality goals need to be defined for the organization, programs and measures determined to help the organization achieve these goals, and documentation of results of quality initiatives provided. Process evaluation, which includes measurement tools, can help determine the status of the process. Monitoring, by measuring the process, assists in providing information to improve troubled areas. The difficulty is to determine what to measure and what tools to use.

There are several factors that influence the organization's ability to produce quality product profitably, as shown in Figure 2-1. The quantity and quality of raw material available influence the time available to make product, as well as the quality of product produced. There is a tradeoff between performing preventive maintenance versus not performing preventive maintenance in order to continue making product. If preventive maintenance is not performed, at some point, the machines will fail. Methods to improve quality product are desirable, since quality product affects profitability. A quality initiative is one method of increasing the amount of product that the customer receives. In later chapters, other methods that can be implemented in conjunction with the quality control program will be examined.

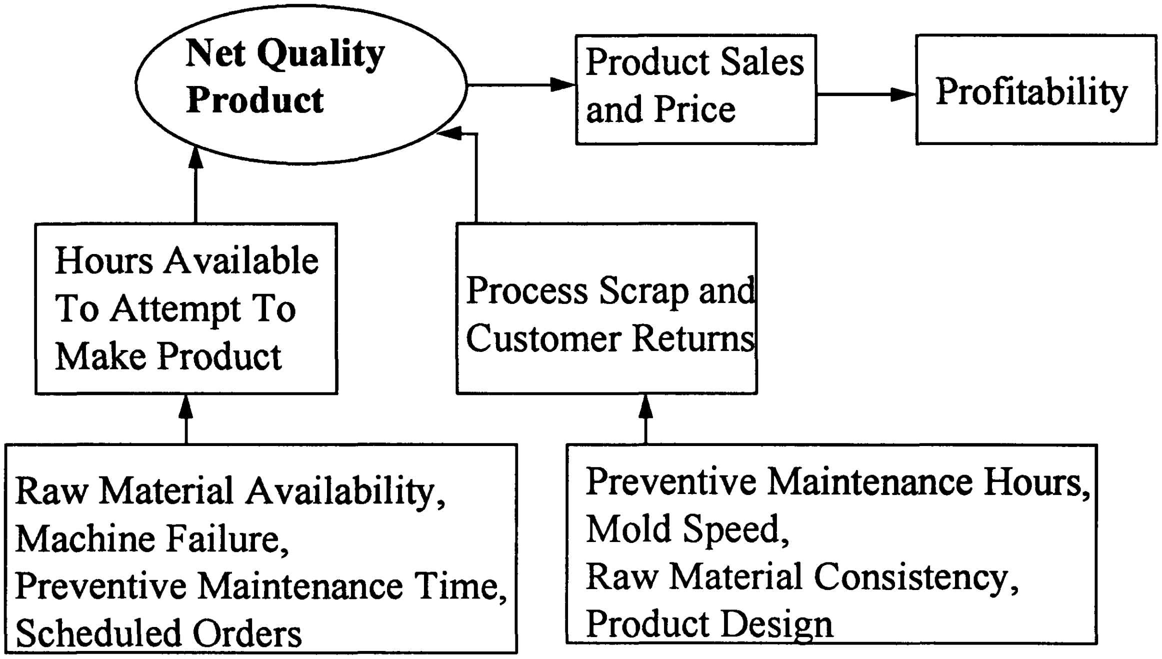

Figure 2-1: There are several factors within manufacturing that can influence the organization's ability to produce quality product profitably.

2.1 Quality Definition

For the gains provided by a focus on quality improvement to be realized, a consistent, unified definition for the division is needed. Quality can be measured by the defect rates or scrap levels. It can also be measured by determining if the product performs according to design when in the market, if delivery times are met, and if prompt, effective service is provided when product issues arise. Garvin, states five major approaches to the definition of quality and eight dimensions of quality.[1] He states that, "both reliability and conformance are closely tied to the manufacturing-based approach to quality. Improvements in both measures are normally viewed as translating directly into quality gains because defects and field failures are regarded as undesirable by virtually all consumers."[1] The quality managers at the majority of locations have statistical process control and cost of quality initiatives in progress in the manufacturing area. These are both conformance quality measurement tools. Another component of conformance quality is establishing accountability for quality.

A quality mandate will need to be initiated from a high level within the business. A division wide standard for quality will allow all of the facilities to share resources to better meet demand fluctuations. Although certain facilities feel that their product quality is adequate for their market, the product quality is known to be unacceptable in other markets. Therefore, a quality standard that will be suitable for all markets or the markets a facility could potentially support will need to be established. This standard will state mold, post-mold, and finishing requirements for the product as well as what raw material requirements are needed.

In order to make quality a competitive advantage there will need to be a cultural change around how quality is viewed within the organization. Vendors will need to be held accountable for providing quality products. If individuals within the organization are unaware of what the appropriate parameters to test incoming material for quality are, then efforts to investigate these parameters will need to be initiated. If quality is to be a priority then a long term investment in it is necessary. The organization will have to undergo a learning process. One result of the learning will be redesigned tasks, processes, procedures and attitudes that ensure quality product is achieved. If the capabilities to move forward with the quality initiative are not presently within the organization, again a long term decision to invest in building and acquiring these capabilities will need to be assessed. The result of a quality initiative should allow the organization to say how they can differentiate themselves in regard to the competition when it comes to quality. The goal of measurement is to help deliver more quality product to the customer effectively.

2.2 Benefits Of Quality

Some of the benefits of quality will be easy to measure, while it will be a challenge to quantify others. Gordon and Wiseman conducted studies of Canadian manufacturers to determine plant best practices and stated that, "the most successful manufacturing plants participating in this survey emphasized quality-related practices over all other manufacturing priorities."[2] When the organization focuses on and accomplishes producing the product to specified requirements the first time through the process, less material will be wasted as scrap, customer returns will be reduced, and capacity to produce additional good product will increase. All of these benefits will improve cost of raw materials, cost of reprocessing customer returns and cost of crediting customer for additional units and possible damages due to defects.[1] Garvin's analysis of the impact of improved quality on profitability is given in the Appendix. Although the business unit understands the customer's perception of quality, it is difficult to determine which parameters influence quality. A quality effort that is made as a long term commitment that results in a change in mind set within the organization will result in intangible benefits such as more orders due to improved customer service and satisfaction, and improved performance in the field. It is not sufficient to have pockets of your organization preaching quality. In Juran's view, top management's role is to ensure that all of the organization is quality focused.[3] As quality levels increase at the various facilities, product performance across facilities will increase, allowing the organization to leverage worldwide capacity.

2.2.1 Relationship with Vendors

Ideally, the facility wants to have enough confidence in supplier quality that raw materials do not need to be checked, but suppliers can adversely affect quality. Long term relationships with suppliers are not sufficient to ensure quality; verification is. To ensure the availability of raw materials the facilities use multiple suppliers, and this increases the likelihood of variation in raw materials. Increased variation will cause operators to adjust machines more frequently. To reduce this variation incoming inspection is needed. An audit program is not enough because it does not guarantee that all product will meet specification.

Due to polymer shortages it is a challenge negotiating terms with suppliers, but if possible, working toward tightening specifications over time can help reduce variation. Melt flow provides the opportunity to characterize polymer chain length. Adding the melt flow at all locations will give at least some check on consistency of product at locations. Also, melt flow on other raw materials used in post-mold processing would be beneficial. Otherwise, there is no way at checking what is being fed to the process. In Chapter 1, the acceptable melt flow range was large. Over time narrowing this range(i.e. 0.9X-1.09X grams, with a target of X) will allow materials with less variation to enter the process. In addition, there is value in examining other testing methods and the potential benefits versus costs. Density measurement would provide additional polymer characterization. A technique for gaining information on appropriate measures is to benchmark what other molding manufacturers do to check suppliers. Possible benchmark candidates are direct competition or molding manufacturer's in another industry, and in addition the experience would be valuable in learning alternative material handling and analysis procedures.

Other factors that contribute to quality are product and process design; customer and technical support and shipping companies. Shipping companies need to be accountable for damaged boxes and late deliveries. Increased design for manufacturability efforts can ensure products that are easier to manufacture. Issues such as improper cooling and tool wear can contribute to product defects. The division can leverage the fact that it is an original equipment manufacturer to learn ways to reduce equipment related defects. Technical and customer support can assist in quality improvements by revising and determining measures, processes and procedures to address root causes of product defect and performance issues.

A material tracking initiative was started at Facility 1 in November 1994 after discrepancies between calculated and reported scrap were emphasized. The purpose of material tracking was to accurately track material usage through the process. The material tracking team defined scrap as all losses of material that occur during the production process, or any material entering into the process not resulting in good product. Presently facility 1 has started to weigh scrap at the end of the shift. When there is a discrepancy between total weighed scrap at the end of a shift and reported scrap, reported is increased to reflect the weighed amount. The present technique does not allow the operators to pinpoint at which process the discrepancy occurs. In the future the facility plans to have scales at every process and as scrap occurs it will be weighed and the reason for scrap recorded. This method will alleviate the need to estimate scrap. The facility is still examining effective ways to measure the total amount of product molded at the molding machine.

Material is considered to enter into the process as soon as it arrives at the facility. Therefore scrap losses could occur before the material was processed and this needs to be captured. Accurate data need to be obtained on where scrap is occurring. Also, working with finance, who keep material variance information, will provide a cross check on data accuracy. Other functions, such as purchasing may also be appropriate to work with. In addition, procedures for material usage between groups such as research and development and machinery will need to be set up.

Early detection of insufficient product quality is essential since as the material is processed it goes through several steps which add value. Therefore, ensuring early on in the process that material meets specifications will reduce the need to scrap product that has had value added to it. The more processing that the product receives, the more value it has, and more costly it is if the product needs to be scrapped. After the molding process the polymer can be recycled, and this scrap does not add significantly to material costs. After post-mold processing and finishing any scrap is sold and cannot be recycled, therefore increasing raw material costs. If product is returned, the costs are significantly higher than if the defect had been identified before the product was shipped. Therefore there may be a tradeoff between higher internal scrap rates to reduce customer returns. Also, a tradeoff between more costly incoming inspection to reduce internal scrap rates can exist. The upfront, proactive investment to ensure quality when the product is still of very low value will reduce costly quality issues later in processing chain. Over time the manufacturing learning curve regarding quality increases and it becomes even more efficient to produce quality product. Fine states that "economic conformance level analysis (i.e. cost of quality minimization) provides an accurate model of the strategic quality optimization problem, but that quality improvement enhances learning about the production process so that the costs of achieving high quality decreases over time and zero defects becomes the long-run cost minimizing quality level."[4]

Chapter 3: Production System Yield Model

The purpose of manufacturing strategy is to establish and implement a method to achieve competitive advantage by determining what capabilities within the organization need to be strengthened and built. Figure 3-1 illustrates the importance of data and accountability throughout the manufacturing strategy process. Consistent and accurate data are essential for any improvement plan, since data provide an indicator of existing performance. Once a baseline level of performance is established, effective plans to improve performance can be created. Progress over time will be monitored to ensure that the intended results are being achieved. In addition, by having all facilities use common metrics performance comparisons are less ambiguous, therefore facilitating communication and sharing of best practices at facilities. Incentives and accountability can influence accuracy of data. To ensure that strategy and improvement programs are on schedule, organizations need to set up data reporting and accountability structure. As business needs change the system will need to respond accordingly or be modified. Reassessment of data collection and measurement systems should occur frequently to ensure that appropriate information is available in a quick and reliable manner.

As the division's facilities began to expand, centralized manufacturing support wanted a standardized method to compare performance across the facilities. It was considered by manufacturing support to be valuable for each facility to more effectively manage their operations by improving utilization of assets. Also, the company needed to increase capacity without investing in additional equipment at certain facilities. The following questions were asked: "Is existing equipment being used to its full potential?" and "Do each of the facilities report performance information in a consistent format?" The Production System Yield (PSY) model was created to address these questions. An increase in Production System Yield would effectively result in a capacity increase.

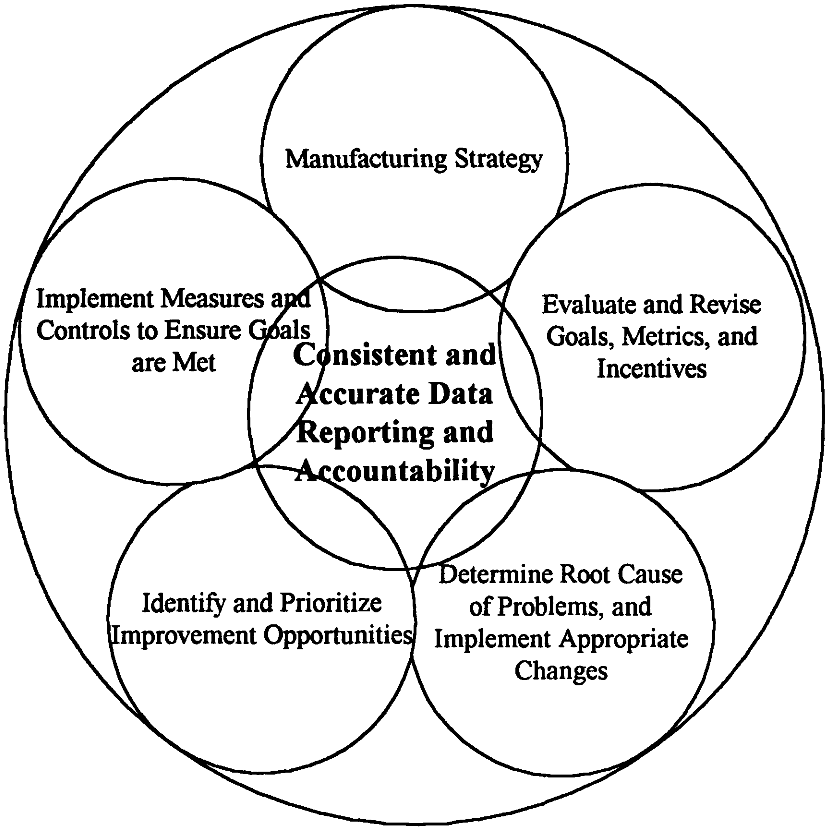

Figure 3-1: The continuous process of updating manufacturing strategy depends heavily on accurate data reporting and accountability.

3.1 PSY: Asset Utilization Model

The PSY model is a facility asset utilization model, developed by centralized manufacturing support. This model is being used to measure performance at facilities over a given time period and to determine areas where productivity improvement efforts can be focused. Kerkhoff provides an example of an asset utilization model used to measure individual machine performance measures to gain manufacturing improvements.[5] Opportunities for improvement are determined by tracking key performance factors that indicate a facility's productivity levels. The five key factors are: Rate of Quality Products, Run Speed Efficiency, Molder Run Hours, Scheduled Time and Net Production Rate. Multiplication of the five factors results in a PSY number. Figure 3-2 provides a summary of the PSY formulas.

$$\text{PSY} = \overset{\boxed{\text{A}}}{\boxed{\text{SCHEDULED TIME \%}}} \text{ X } \overset{\boxed{\text{B}}}{\boxed{\text{RATE\% QUALITY PRODUCTS}}} \text{ X } \overset{\boxed{\text{C}}}{\boxed{\text{RUN SPEED EFFICIENCY\%}}} \text{ X } \overset{\boxed{\text{D}}}{\boxed{\text{MOLDER RUN HOURS \%}}} \text{ X } \overset{\boxed{\text{E}}}{\boxed{\text{NET PROD RATE \%}}}$$

A	B	C	D	E
$\frac{\text{SCHEDULED HOURS}}{\text{\#MOLDERS X CALENDAR HRS}}$	$\frac{\text{PACKED + WIP}\Delta}{\text{TOTAL MOLDED}}$	$\frac{\text{(TOTAL MOLDED/RUN MIN)}}{\text{DESIGN SPEED}}$	$\frac{\text{RUN HOURS}}{\text{SCHEDULED HOURS}}$	$\frac{\text{PACKED - RETURNS - INV OBS}}{\text{PACKED}}$
IDLE TIME LOSSES	CLOSURE SCRAP RATE	MOLDER SPEED	DOWNTIME %	
1 - A	1-B	DESIGN SPEED X C	1-D	

Figure 3-2: Multiplication of the five key factors results in Production System Yield number. Formula for each key factor is shown above.

3.1.1 Components Of The PSY Model

Scheduled Time Percent, component A of the PSY formula in Figure 3-2, measures the amount of time the facility was scheduled to operate against calendar hours. Scheduled time percentage is calculated by dividing scheduled molder hours by the quantity number of molders times calendar hours. Idle time losses equals 100 percent minus Scheduled Time percent. Preventative maintenance is not an idle time loss, but is considered under downtime. The model tracks the idle time losses such as seasonality, material shortages, insufficient crewing, and no tooling. Also, sales versus projected production, order lead times and equipment shortages are tracked in an effort to focus on what idle time losses are occurring.

Rate of quality products, component B, measures the amount of quality sellable product being boxed (packed) and ready for shipment to the customers. This is calculated by dividing the quantity packed product plus change in Work in Progress(WIP) by total product molded. Scrap equals 100 percent minus Rate of Quality Products percent. Pareto charts of scrap by process, product, machine, and scrap cause by process assist in understanding the calculated rate of quality products.

Run Speed Efficiency, component C, measures the performance of the molding machines against the manufacturer's design speed. This is calculated by dividing the total quantity molded product by machine run minutes (minutes machine operating and producing product) and by design speed. The molder speed is calculated by multiplying the design speed by the run speed efficiency. The model provides a Pareto of molder set speed by product and color, since the run speed efficiency is based on a weighted product speed average.

Molder run hours, component D of the PSY formula in Figure 3-2, is the percentage of operating time that the molding machine is actually operating and producing product. While operating, the product produced is either sellable product or scrapped product. Molder run hours is calculated by dividing machine run hours (hours molding machine is operating and producing product) by the scheduled molder hours(hours molding machine is scheduled to operate). Downtime is the percentage of time a molding machine was scheduled to operate but is not operating. Downtime equals 100 percent minus Machine Run Hours percent. The PSY model then creates Pareto charts[**] of the downtime reasons and tracks specific indicators such as turnover, absenteeism, and training hours to assist in understanding why the machine is down.

Net Production Rate, component E, tracks how much product remains sold. It is calculated by subtracting returns and inventory obsolescence from the quantity packed product and then dividing by packed product. The model tracks inventory obsolescence and customer returns. Other information that is pertinent to the facility's production can

---

[**] A pareto chart is a bar graph that ranks the biggest problems on the left followed by lesser problems. Arranging problems in this order helps in determining which problem to attack first.

be found on the model. Product mix, closure colors, closure liners, score design, serious injury rate, closure complaint rate, and a Pareto of top production system losses.

The PSY number can also be determined by the number of units packed and ready for shipment minus the units that are returned and the units that are unsaleable(become obsolete in inventory) divided by the theoretical production potential for the facility over a given time period. Also the formula factors in work in process (WIP) changes during the time period. This alternative formula is given in Figure 3-3.

$$\text{PSY} = \frac{\text{PACKED - RETURNS - INV OBS + WIP } \triangle}{\text{DESIGN SPEED x \# MOLDERS x CALENDAR HRS x 60}}$$

Figure 3-3: Alternative method of calculating PSY number.

PSY can be calculated on a year to date (YTD) basis to indicate present performance or on an estimated yearly basis to look at expected performance. With a make to order strategy the first six months of the year may have a high average PSY due to seasonality of the business, but the yearly estimated PSY may be much lower due to anticipated sales decline. With a make to stock strategy the amount of packed product could increase, but it may not be shipped to the customer. An example of a production system yield model is shown in Figure 3-4.

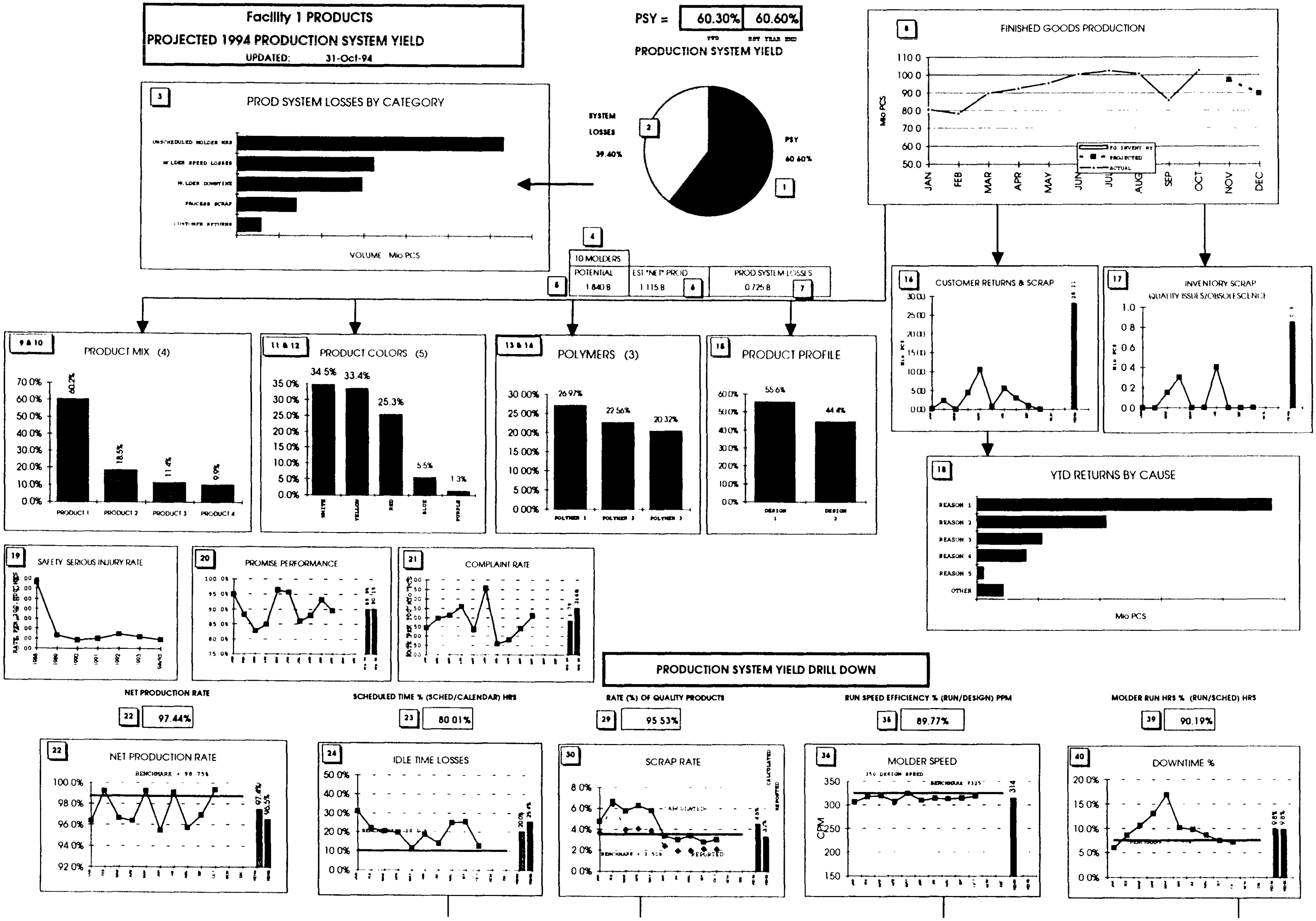

Figure 3-4: The PSY Model.

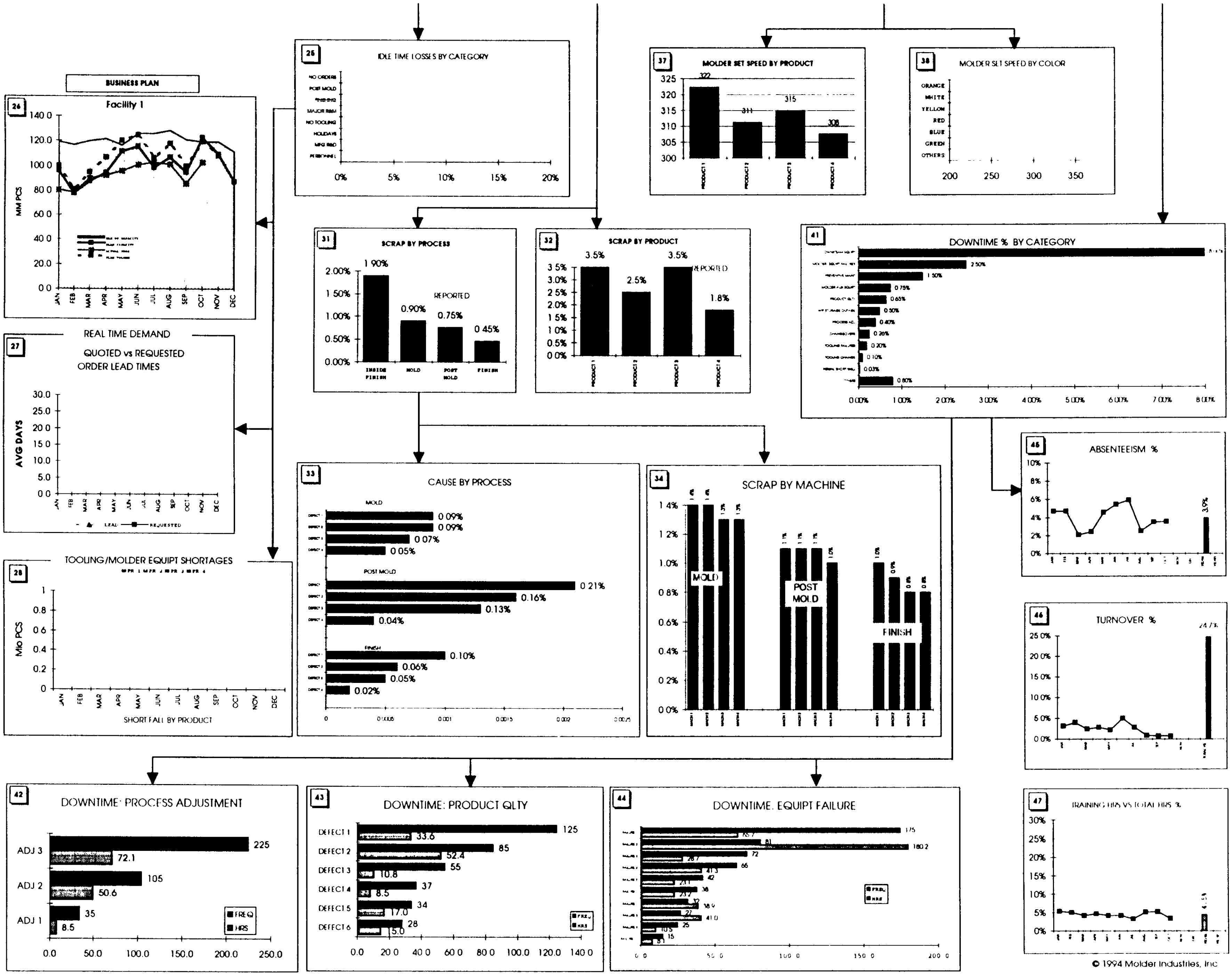

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Figure 3-4: The PSY Model.

3.2 Analysis of PSY Model

After examining historical data for all facilities, a benchmark level of PSY was determined. The facility that had sustained as a yearly average the highest level in a certain factor was used as a benchmark for the given factor. Then, the five factors were multiplied together to establish the benchmark PSY number. None of the facilities presently have attained the benchmark PSY number, although some are close. A framework for analysis of each facility's PSY was established. See PSY Review Process in Figure 3-5. The review process has a location compare its PSY number and level of performance in each of the five factors to the benchmark level. In the PSY model the factors and PSY number have supporting data that would be analyzed to determine how to reach or exceed benchmark levels in each area. At the end of the review process the facility's improvement action plan would be updated to incorporate projects that increase PSY.

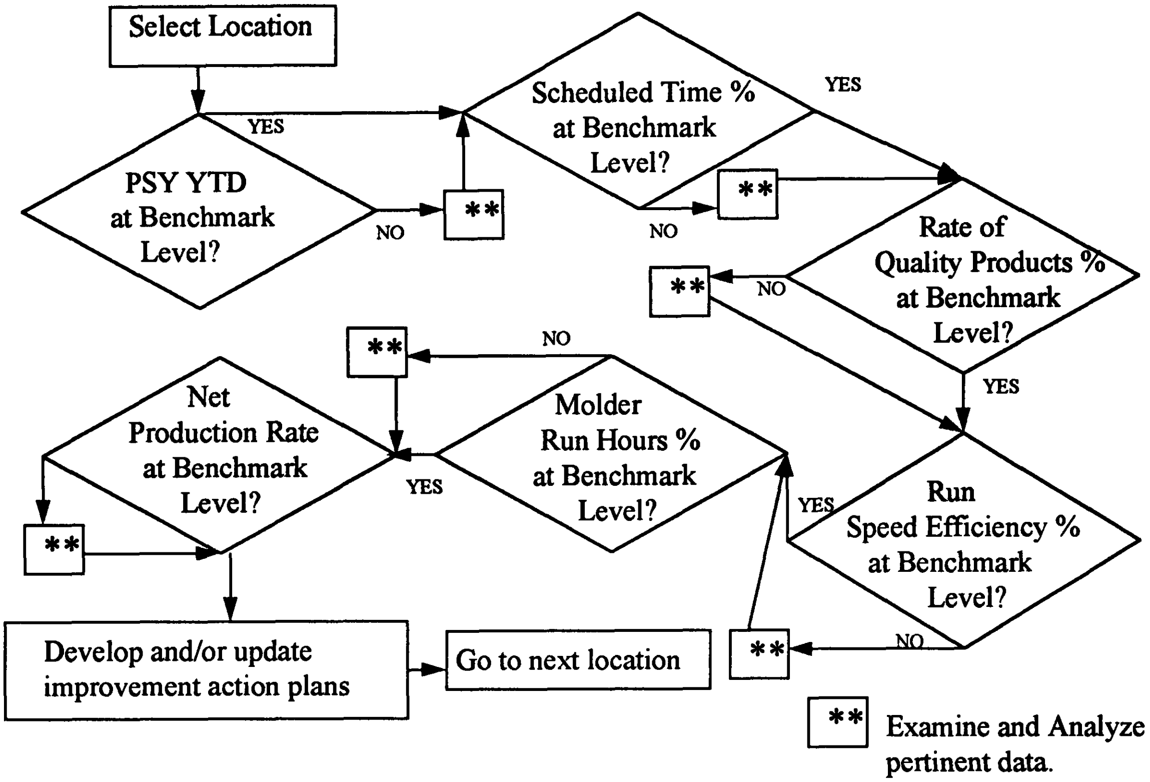

Figure 3-5: The PSY review process.

PSY targets were set for the worldwide organization. A one percent PSY improvement would result in more product to the customer. There is a 35 percent difference between high and low year to date PSY for worldwide facilities. A ten percent increase in PSY results in effectively a ten percent increase in capacity. In Figure 3-6 the components of PSY for Facility 1 are graphed. Monthly Percent Scheduled Time positively correlated with monthly PSY over time. Scheduled time is an indicator where very little data is presently recorded, but an increase in scheduled time will have the largest impact on PSY. A larger increase in PSY will result by focusing on those factors with the lowest percentages. This graph shows that PSY X Month and Scheduled Time have the same trend. There is more variation monthly in Shipped PSY than PSY X Month . When Shipped and monthly PSY are the same that means that the packed product equaled the amount of product shipped in a given month. The year to date PSY numbers for Shipped PSY and PSY X Month are very similar.

The PSY data revealed discrepancies in reporting. The Product Scrap Rate that was calculated using the model was very different than the reported scrap rate at both facilities. A team was set up to close the gap between reported and calculated scrap rate and to implement procedures that would improve the accuracy of data collection, and identify ways to reduce scrap losses. Facility 2 changed the definition of certain downtime codes in August and this resulted in a much lower Molder Run Hours Percent for August, September and October. Top downtime reasons generally included preventive maintenance for most facilities. Other top downtime reasons were facility specific. As a result of PSY analysis downtime codes would be reevaluated and operators retrained to ensure downtime reasons that addressed root causes were being recorded. It was believed that improved product design was the way for machine speeds to be increased.

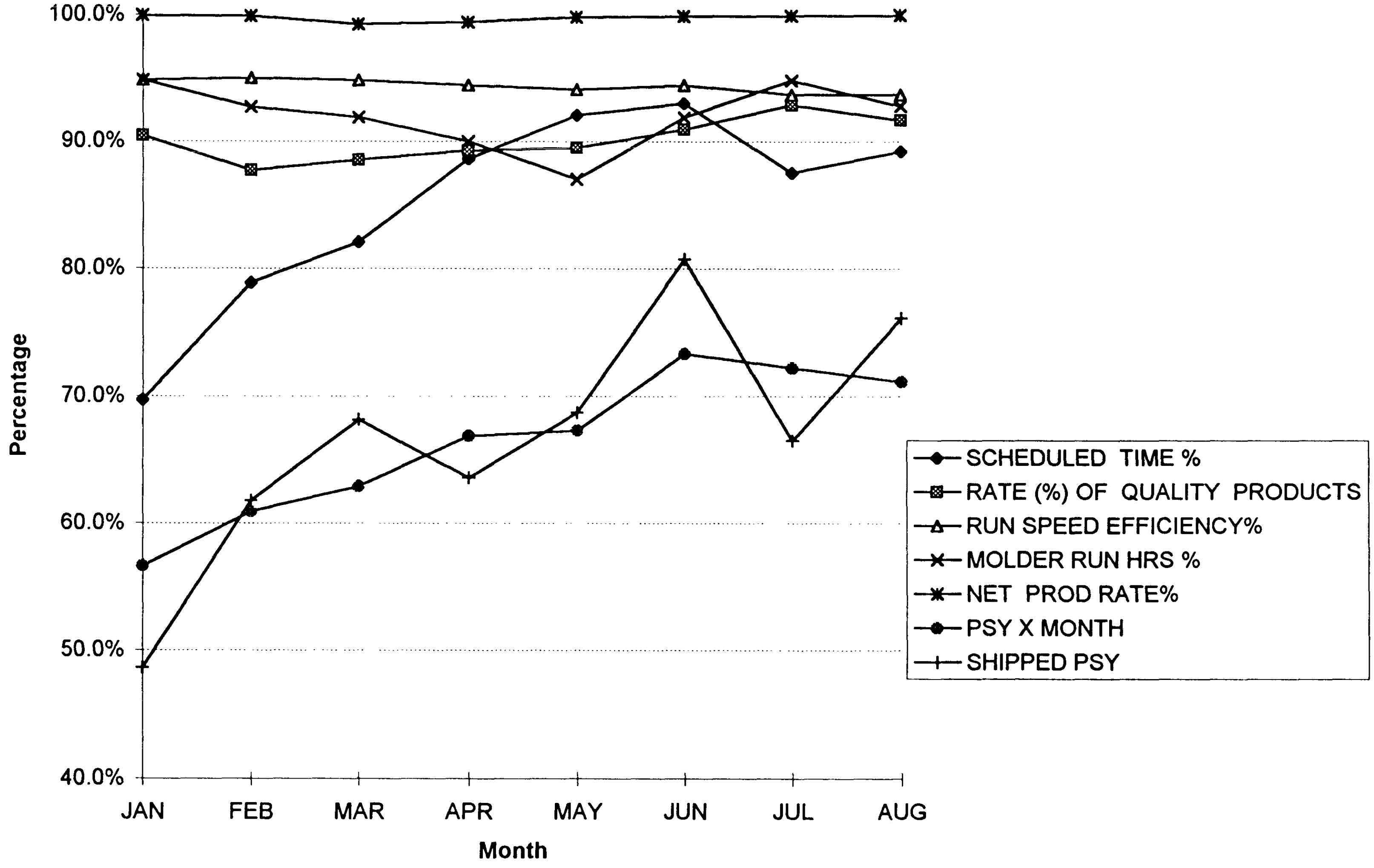

Figure 3-6: PSY Components of Facility 1.

3.3 Applications of PSY

Facilities staff believed that comparing PSY models directly was inappropriate given the different product mixes of facilities. Some facilities produce only two products with two different color combinations, while others may make eight different products with 36 color combinations. A PSY model can be set up for a specific product within a facility, and a common product at two facilities can be compared. Also, a PSY model can be set up for a plant that is starting up to begin to track their performance.

A comparison of two facilities running the same product is given in Figure 3-7. The color combinations were approximately equal at both facilities. Color combination is important since certain colors can affect speed in either direction. This is a product line where more capacity is needed, therefore any improvements will result in increased product to customer (and increased PSY). The run speed efficiency at both facilities appeared too high, while rate of quality products was low. A further investigation into this led to the discovery that total molded was an estimated number, and it was being over estimated. When total molded was lowered at both facilities to reflect actual machine speeds, run speed efficiency dropped. Rate of quality products increased, therefore causing no change in PSY but giving a more accurate picture of where improvement opportunities were. Actually, the facility had a reported scrap rate that was still lower than the adjusted scrap rate with the modified rate of quality products. Closing this gap became one of the improvement objectives. The facility that had a higher facility PSY also had a higher product PSY for this particular product.

Summary

Initial Analysis

Facility 1 — **Product #1 primarily produced in Cell 1 and Cell 2**

1994 Month	*Scheduled Time%*	*Rate of Quality Products%*	*Run Speed Eff. %*	*Molder Run Hours%*	*PSY*
May	83.3%	84.8%	110.4%	87.6%	68.3%
June	93.9%	85.1%	102.4%	91.4%	74.8%
July	80.8%	86.2%	103.3%	94.8%	68.1%
August	86.5%	84.8%	102.4%	88.9%	66.8%
AVERAGE	**86.1%**	**85.2%**	**104.6%**	**90.7%**	**69.6%**

Facility 2 — **Product #1 primarily produced in Cell 3 and Cell 4**

1994 Month	*Scheduled Time%*	*Rate of Quality Products%*	*Run Speed Eff. %*	*Molder Run Hours%*	*PSY*
May	78.0%	97.6%	86.8%	96.0%	63.4%
June	77.5%	93.3%	97.8%	95.1%	67.3%
July	72.0%	91.2%	86.6%	94.0%	53.5%
August	68.5%	94.7%	93.4%	81.8%	49.6%
AVERAGE	**74.0%**	**94.2%**	**91.1%**	**91.7%**	**58.3%**

**At a Run Speed Efficiency of 104.6% Facility 1 would be producing caps 12% above reported speeds. Facility 2 would be producing caps 3% above reported speeds.

During May through Aug. Facility 1 was operating between 8.5 and 9 machines with Product #1 and Facility 2 was operating 10 machines.

Revised Analysis

May-Aug. 1994	**Facility 1**	**Facility2**
Scheduled Hours	4,447	4,336
% Utl	90.7%	91.7%
Run Hours	4,033	3,977
Calendar Hrs	5,165	5,856
Good Output-Mold	*Decided to base the Total Molded*	
%Scrap Reject	*on RunHours* Reported Speed*	
Total Reject-Mold		
Total Molded	840,124	793,769
Total Packed	807,761	769,938
Scheduled Time%	86.1%	74.0%
Quality Products%	96.1%	97.0%
Run Speed Eff %	92.6%	88.7%
Molder Run Hrs%	90.7%	91.7%
PSY	**69.5%**	**58.4%**

This revised analysis shows Rate of Quality Products closer to what is expected. The major difference between the two facilities is Scheduled Time%.

Figure 3-7: Product specific PSY comparison of two facilities. Net Production Rate at both facilities was assumed to be 100%. The Initial Analysis was revised to more accurately reflect operating performance.

This product PSY analysis can be used to evaluate standard operating policies such as one facility running the same product at a slower speed. Facility one, with a faster machine speed, provided more product to the customer using one less machine during the same time period than facility two. Facility one had a slightly lower rate of quality products, but this could be the tradeoff of running faster. Also, looking at the data, there is a significant difference in scheduled time between the two facilities. More investigation into the discrepancy revealed that facility 2 had not staffed for the present demand levels, and other issues such as absenteeism and employee turnover were causing a lower scheduled time.

3.4 Limitations of PSY

PSY can be used as a high level tool to identify significant improvement opportunities. To enhance the model's effectiveness it needs to be used in conjuction with other data. Those using the model need to realize how data are being obtained, so that they can assess its accuracy. If measures are not in place for areas where data are needed a process to obtain information will need to be developed. This model is data intensive, and data entry is an issue. Presently, the model is being updated on a monthly basis, but the facilities that desire to use the model want to be able to update it on a weekly or daily basis. Suggestions and buy in from individuals who have to collect the data are needed for successful implementation.

There is very little data on idle time losses, and more is needed since it has a large influence on Production System Yield. One reason that the facility cannot be fully scheduled is due to tooling shortages. Tooling shortages are not desirable if there is free capacity. Tools are a capital investment, but given the potential monetary profits, excess tooling could make sense.

In the model Pareto charts are created from reported data. Pareto charts will assist in answering questions about where to close gaps. Monthly run charts will assist in determining root cause of a change over time. The five factors are calculated. When there is a discrepancy between the calculated factor, and reported information, i.e. Rate of Quality Products, how helpful are the data in understanding why there is a gap and where efforts to close the gap should be focused? Other information not available in the model will have to be brought in to determine what is causing the gap.

There are 100 downtime codes for molding. A review needs to be made to determine if any of these codes can be grouped together into broader areas. Downtime may be decreased with increased communication and coordination between machine operators. Also, when addressing downtime issues the downtime information only looks at information on molder downtime. When Downstream Process down is a high downtime reason, information that provides insight into downtime for the other processes is needed.

Although 100 percent is an unrealistic goal, given the right circumstances benchmark performance is attainable. Preventative maintenance and major repair and maintenance need to happen otherwise the machines would constantly be shutting down. Everything is on a molder basis. This may not be the bottleneck of the process given the product profile. Even if a facility does not run a seven day week, theoretical capacity is based on this. So that barriers to increasing capacity can be understood, staff at facilities using the PSY model should increase interaction involving comparison of standard measures and sharing of best practices.

Given the initial work with the Production System Yield Model the following parameters are key focus areas: quality, idle time losses(tool shortages), speed, downtime codes. A coherent plan that addresses these areas and incorporates them into manufacturing strategy will be a start at building long term capabilities.

Chapter 4: Production Planning Model

Planning allows an organization the opportunity to anticipate and prepare for customer orders. The ability to produce customer orders affects customer loyalty and goodwill, as shown in Figure 4-1. To ensure that no orders are delayed or missed there is a customer satisfaction tradeoff, as well as, a cost and feasibility tradeoff regarding capacity. Orders may have to be delayed if no material is available. Although adding machinery is costly, it may provide needed extra capacity. Productivity improvements occur over time, and it is harder to predict when a capacity increase due to productivity improvements will be available. Other methods of increasing capacity include inventory leveling, support from other facilities, and varying labor usage. To minimize inconvenience to the customer, considering alternative plans will allow the facilities to be prepared when demand changes, or capacity is constrained, given existing machines, materials and production plan.

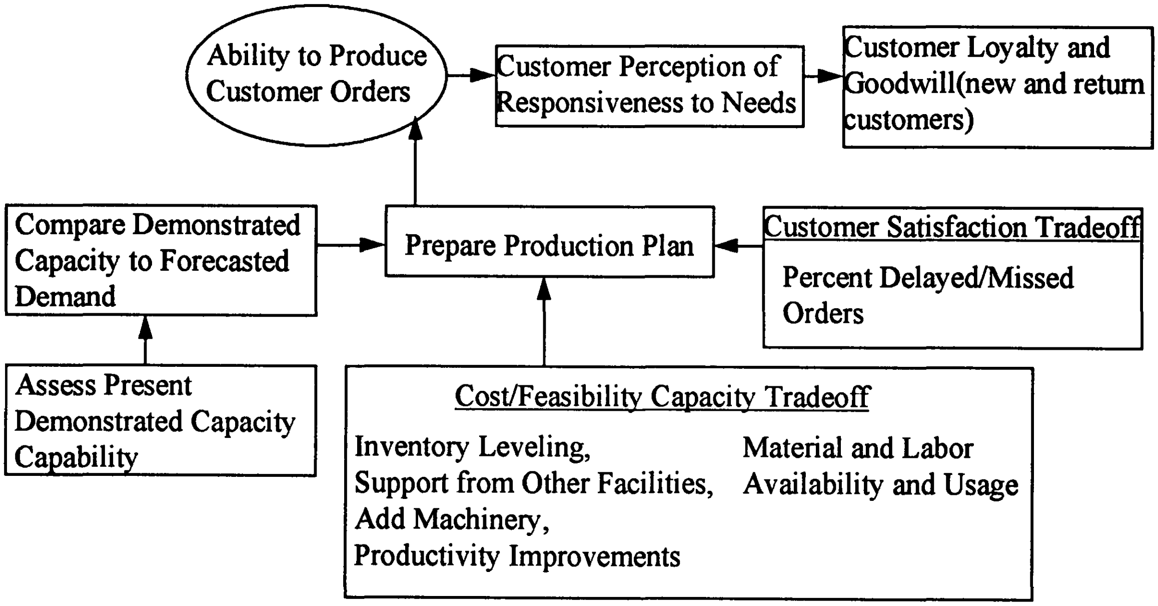

Figure 4-1: The ability to produce customer orders on time affects customer loyalty and goodwill.

The purposes of the production planning model are to assist management in making decisions about the business unit on a regional level, and to assist management in establishing a stronger communication link with all functions of the organization. The major components of the production planning model are aggregate sales, theoretical capacity, speed adjustments, capacity adjustments, demonstrated capacity, production/inventory plan and materials requirements. The production planning model is a spreadsheet tool that incorporates information from the PSY model to establish demonstrated capacity, indicates major product loss categories and how these impact capacity, provides ability to analyze various demand scenarios, determines amount of good product a region is capable of producing on an aggregate level and determines the amount of polymer needed for this production level. The production planning model links forecasted demand with demonstrated capacity to determine a production plan and materials requirements. Raw material requirements are necessary well in advance due to material shortages. Also, when demand exceeds capacity, advance planning assists in establishing methods to minimize or avoid product shortfalls. Various management decisions can be considered with this model to understand how certain decisions influence demonstrated capacity, the production plan, and materials requirements. Also, this tool addresses how changes in the demand will affect the region's ability to meet customer orders. The model covers a two-year time frame, in monthly increments at a regional level. This region can be serviced by one or multiple plants. Generally, facilities do their own planning. Regional planning on aggregate level provides more flexibility in determining how to best use assets to meet customer orders.

4.1 Components Of Production Planning Model

An example of a production planning model is shown in Figure 4-2. The components of the model are explained below.

4.1.1 Aggregate Sales

Aggregate sales is the forecasted sales for the region of interest. In section 1A of the model forecasted sales for 1995 are shown. Generally, there is wide variation in the accuracy of the forecasted demand. To determine the impact of a low sales forecast the forecasted 1995 sales were increased by 15 percent each month (and is stated as 1995-15%). Although it is not provided in the example, sales below 15 percent could also be evaluated. Forecasted sales for 1996 are shown. The value of having two years of forecasted sales information ensures that December 1995 production plan is based on ability to meet customer orders in the future versus ability to meet end of the year production goals. The monthly expected sales information is then discussed with all functions and will be used to establish a monthly production plan. Depending on the manufacturing strategy, the amount of product produced in a given month may be different than the amount of product sold.

4.1.2 Theoretical Capacity

The theoretical capacity is the monthly product output for 365 days of production, given the number of molders within the region and the molder design speed. Capacity is based on molding since the process is designed for molding to be the rate limiting step. In section 1B output for 1995 and 1996 are given in z units.* This example shows theoretical yearly output for 1995 and 1996 at 120 z. These yearly outputs could differ if additional molders were added over time or design speed increased as result of machine modifications. Generally, the region will not be producing product at the theoretical capacity due to holidays, slower machine speeds, preventive maintenance and other capacity losses.

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* z is picked as the unit of measure for the examples throughout the text, but the author does not specify further detail in order to maintain facility confidentiality.

		Production Planning - z units											
	Demand	Management Array											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1A: Aggregate Sales													
1995	5.70	5.71	6.26	6.97	7.71	8.07	7.43	7.80	6.35	6.14	5.97	5.74	79.85
1995-15%	6.55	6.57	7.20	8.01	8.87	9.28	8.55	8.97	7.31	7.06	6.87	6.60	91.83
1996	5.81	5.83	6.39	7.11	7.86	8.23	7.58	7.95	6.48	6.27	6.09	5.85	81.45
1B: Theoretical Capacity													
1995													
Number of Molders	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
Number of days per Month	31	28	31	30	31	30	31	31	30	31	30	31	365
Output- % Theoretical Capacity	100	100	100	100	100	100	100	100	100	100	100	100	
Output	10.21	9.22	10.21	9.88	10.21	9.88	10.21	10.21	9.88	10.21	9.88	10.21	120.23
1996													
Number of Molders	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
Number of days per Month	31	28	31	30	31	30	31	31	30	31	30	31	
Output- % Theoretical Capacity	100	100	100	100	100	100	100	100	100	100	100	100	
Output	10.21	9.22	10.21	9.88	10.21	9.88	10.21	10.21	9.88	10.21	9.88	10.21	120.23
1C: Speed Adjustments 1995													
1995-Demonstrated %	90	90	90	90	90	90	90	90	90	90	90	90	
Molder Speed Loss-UPC	52.4	52.4	52.4	52.4	52.4	52.4	52.4	52.4	52.4	52.4	52.4	52.4	
Product Loss due to Speed	1.0	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	11.7
Revised Output	9.2	8.3	9.2	8.9	9.2	8.9	9.2	9.2	8.9	9.2	8.9	9.2	108.6
											Percent loss		10%
1D: Capacity Adjustments													
1995													
Lost Production Time													
Employee Absence- hrs.	145	145	145	145	145	145	145	145	145	145	145	145	
Product Losses due to Abs.	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.35
Holidays	1	0	0	1	1	0	1	0	1	0	2	3	10
Product loss due to Holidays	0.30	0.00	0.00	0.30	0.30	0.00	0.30	0.00	0.30	0.00	0.59	0.89	2.97
Major R&M-Mach Days Down	15	0	15	0	15	0	15	0	15	0	15	0	90
Product losses due to R&M	0.07	0.00	0.07	0.00	0.07	0.00	0.07	0.00	0.07	0.00	0.07	0.00	0.44
PM Machine Days Lost	5.09	5.09	5.09	5.09	5.09	5.09	5.09	5.09	5.09	5.09	5.09	5.09	61.05
Product losses due to PM	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.30
Molding Equip Failures in Hrs	474	474	474	474	474	474	474	474	474	474	474	474	
Prod losses due to Equip. Fail.	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	1.16

Figure 4-2: The production planning model links forecasted demand with demonstrated capacity to determine a production plan and material requirements.

All Other Down time-Hrs	1357	1357	1357	1357	1357	1357	1357	1357	1357	1357	1357	1357	
Prod losses due to All Other	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	3.31
Scrap(7.9%)													
% Due to Mold	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	
Prod losses due to Mold	0.11	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.34
% Due to Post-Mold	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	
Prod losses due to Post Mold	0.08	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.95
% Due to Finishing	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	
Prod losses due to Finishing	0.05	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.56
% Due to Inside Finish	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	
Prod losses due to Inside Finsh	0.07	0.06	0.07	0.06	0.07	0.06	0.07	0.07	0.06	0.07	0.06	0.07	0.78
% Due to Other	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	
Prod losses due to Other	0.49	0.44	0.49	0.47	0.49	0.47	0.49	0.49	0.47	0.49	0.47	0.49	5.75
Total Scrap	0.80	0.72	0.80	0.77	0.80	0.77	0.80	0.80	0.77	0.80	0.77	0.80	9.38
Prod Losses due to tool short	0	0.063	0	0.579	0.631	1.654	0.85	1.425	0.714	0.374	0.072	0.268	6.63
Total losses By Month	1.59	1.21	1.30	2.07	2.22	2.85	2.44	2.65	2.28	1.60	1.94	2.38	24.53
										Percent Loss=			23%
1E: Demonstrated Capacity	7.6	7.1	7.9	6.8	7.0	6.1	6.8	6.6	6.6	7.6	7.0	6.8	84.03
1F: 1995 Prod/Inventory Plan													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Beginning Inventory	0.30	2.20	3.59	5.22	5.06	4.35	2.38	1.74	0.45	0.59	1.95	2.88	
1995 Demand	5.70	5.71	6.26	6.97	7.71	8.07	7.43	7.80	6.35	6.14	5.97	5.74	79.85
Production Plan-Useable Units	7.60	7.10	7.90	6.80	7.00	6.10	6.80	6.50	6.50	7.50	6.90	6.70	83.40
Ending Inventory	2.20	3.59	5.22	5.06	4.35	2.38	1.74	0.45	0.59	1.95	2.88	3.85	
Inventory Target	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	
Difference to Target	-0.80	0.59	2.22	2.06	1.35	-0.62	-1.26	-2.55	-2.41	-1.05	-0.12	0.85	
Excess Demonstrated Capacity	0.03	0.02	0.02	0.05	0.00	-0.03	-0.02	0.07	0.14	0.12	0.09	0.14	0.63
1G: Polymer Requirements in MM lbs													
Beginning Inventory	0.50	0.30	0.59	0.13	0.64	0.96	2.08	2.57	3.33	4.10	2.98	2.41	
Production Requirement	6.59	6.15	6.85	5.89	6.07	5.29	5.89	5.63	5.63	6.50	5.98	5.81	72.30
Wasted as Scrap	0.61	0.55	0.61	0.59	0.61	0.59	0.61	0.61	0.59	0.61	0.59	0.61	7.21
Receipts	7	7	7	7	7	7	7	7	7	6	6	6	81
Ending Inventory	0.30	0.59	0.13	0.64	0.96	2.08	2.57	3.33	4.10	2.98	2.41	1.99	
Inventory Target	1	1	1	1	1	1	1	1	1	1	1	1	
Difference to Target	-0.70	-0.41	-0.87	-0.36	-0.04	1.08	1.57	2.33	3.10	1.98	1.41	0.99	
										Total Needs less receipt			$ (1.49)

Figure 4-2: The production planning model links forecasted demand with demonstrated capacity to determine a production plan and material requirements.

1H: 1995- 15% Prod/Inventory Plan													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Beginning Inventory	0.3	1.35	1.88	2.57	1.36	-0.51	-3.69	-5.43	-7.80	-8.51	-7.97	-7.84	
1995-15% Demand	6.55	6.57	7.20	8.01	8.87	9.28	8.55	8.97	7.31	7.06	6.87	6.60	91.83
Production Plan-Useable Units	7.6	7.1	7.9	6.8	7	6.1	6.8	6.6	6.6	7.6	7	6.8	83.9
Ending Inventory	1.35	1.88	2.57	1.36	-0.51	-3.69	-5.43	-7.80	-8.51	-7.97	-7.84	-7.63	
Inventory Target	3	3	3	3	3	3	3	3	3	3	3	3	
Difference to Target	-1.65	-1.12	-0.43	-1.64	-3.51	-6.69	-8.43	-10.80	-11.51	-10.97	-10.84	-10.63	
Excess Demonstrated Capacity	0.03	0.02	0.02	0.05	0.00	-0.03	-0.02	-0.03	0.04	0.02	-0.01	0.04	0.13
1I: Polymer Requirements in MM lbs													
Beginning Inventory	0.5	0.30	0.59	0.13	0.64	0.96	2.08	2.57	3.24	3.93	2.72	2.06	
Production Requirement	6.59	6.15	6.85	5.89	6.07	5.29	5.89	5.72	5.72	6.59	6.07	5.89	72.73
Wasted as Scrap	0.61	0.55	0.61	0.59	0.61	0.59	0.61	0.61	0.59	0.61	0.59	0.61	7.21
Receipts	7	7	7	7	7	7	7	7	7	6	6	6	81
Ending Inventory	0.30	0.59	0.13	0.64	0.96	2.08	2.57	3.24	3.93	2.72	2.06	1.56	
Inventory Target	1	1	1	1	1	1	1	1	1	1	1	1	
Difference to Target	-0.70	-0.41	-0.87	-0.36	-0.04	1.08	1.57	2.24	2.93	1.72	1.06	0.56	
										Total Needs less receipt			-1.0558
1J: Speed Adjustments 1996													
1996-Demonstrated %	90	90	90	90	90	90	90	90	90	90	90	90	
Molder Speed Loss-UPC	52.42	52.42	52.42	52.42	52.42	52.42	52.42	52.42	52.42	52.42	52.42	52.42	
Prod. Loss due to Speed	0.99	0.90	0.99	0.96	0.99	0.96	0.99	0.99	0.96	0.99	0.96	0.99	11.671
Revised Output	9.22	8.33	9.22	8.92	9.22	8.92	9.22	9.22	8.92	9.22	8.92	9.22	108.56
											Percent loss		10%
1K: Capacity Adjustments													
1996													
Lost Production Time													
Employee Absence- hrs.	145	145	145	145	145	145	145	145	145	145	145	145	
Prod. Losses due to Abs	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.35
Holidays	1	0	0	1	1	0	1	0	1	0	2	3	10
Prod loss due to Holidays	0.30	0.00	0.00	0.30	0.30	0.00	0.30	0.00	0.30	0.00	0.59	0.89	2.97
Major R&M-Mach Days Down	15	0	15	0	15	0	15	0	15	0	15	0	90
Prod losses due to R&M	0.07	0.00	0.07	0.00	0.07	0.00	0.07	0.00	0.07	0.00	0.07	0.00	0.44
PM Machine Days Lost	5.09	5.09	5.09	5.09	5.09	5.09	5.09	5.09	5.09	5.09	5.09	5.09	61.05
Prod losses due to PM	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.30
Molding Equip Failures in Hrs	474	474	474	474	474	474	474	474	474	474	474	474	
Prod losses due to Equip. Fail.	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	1.16
All Other Down time-Hrs	1357	1357	1357	1357	1357	1357	1357	1357	1357	1357	1357	1357	
Prod losses due to All Other	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	3.31

Figure 4-2: The production planning model links forecasted demand with demonstrated capacity to determine a production plan and material requirements.

Scrap(7.9%)													
% Due to Mold	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	
Prod losses due to Mold	0.11	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.34
% Due to Post-Mold	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	
Prod losses due to Post Mold	0.08	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.95
% Due to Finishing	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	
Prod losses due to Finishing	0.05	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.56
% Due to Inside Finish	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	
Prod losses due to Inside Finish	0.07	0.06	0.07	0.06	0.07	0.06	0.07	0.07	0.06	0.07	0.06	0.07	0.78
% Due to Other	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	
Prod losses due to Other	0.49	0.44	0.49	0.47	0.49	0.47	0.49	0.49	0.47	0.49	0.47	0.49	5.75
Total Scrap	0.80	0.72	0.80	0.77	0.80	0.77	0.80	0.80	0.77	0.80	0.77	0.80	9.38
Prod Losses due to tool short	0	0.063	0	0.579	0.631	1.654	0.85	1.425	0.714	0.374	0.072	0.268	6.63
Total losses By Month	1.59	1.21	1.30	2.07	2.22	2.85	2.44	2.65	2.28	1.60	1.94	2.38	24.53
										Percent Loss=			23%
1L: Demonstrated Capacity	7.63	7.12	7.92	6.85	7.00	6.07	6.78	6.57	6.64	7.62	6.99	6.84	84.03
1M: 1996 Prod/Inventory Plan													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Beginning Inventory	3.85	5.63	6.91	8.42	8.11	7.24	5.11	4.33	2.98	3.10	4.43	5.34	
1996 Demand	5.81	5.83	6.39	7.11	7.86	8.23	7.58	7.95	6.48	6.27	6.09	5.85	81.45
Production Plan-Useable Caps	7.6	7.1	7.9	6.8	7	6.1	6.8	6.6	6.6	7.6	7	6.8	83.9
Ending Inventory	5.63	6.91	8.42	8.11	7.24	5.11	4.33	2.98	3.10	4.43	5.34	6.29	
Inventory Target	3	3	3	3	3	3	3	3	3	3	3	3	
Difference to Target	2.6343	3.9053	5.4154	5.1085	4.244	2.1147	1.3323	-0.022	0.0988	1.433	2.3433	3.2935	
Excess Demonstrated Capacity	0.03	0.02	0.02	0.05	0.00	-0.03	-0.02	-0.03	0.04	0.02	-0.01	0.04	0.13
1N: Polymer Requirements in MM lbs													
Beginning Inventory	0.5	0.3	0.6	0.1	0.6	1.0	2.1	2.6	3.2	3.9	2.7	2.1	
Production Requirement	6.6	6.2	6.8	5.9	6.1	5.3	5.9	5.7	5.7	6.6	6.1	5.9	72.731
Wasted as Scrap	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	7.213
Receipts	7	7	7	7	7	7	7	7	7	6	6	6	81
Ending Inventory	0.3	0.6	0.1	0.6	1.0	2.1	2.6	3.2	3.9	2.7	2.1	1.6	
Inventory Target	1	1	1	1	1	1	1	1	1	1	1	1	
Difference to Target	-0.7	-0.4	-0.9	-0.4	0.0	1.1	1.6	2.2	2.9	1.7	1.1	0.6	
										Total Needs less receipt			$ (1.06)

Figure 4-2: The production planning model links forecasted demand with demonstrated capacity to determine a production plan and material requirements.

4.1.3 Speed Adjustments

Speed adjustments are a revised output based on product losses due to speed. In section 1C demonstrated UPC(units per time cycle) or actual machine speed is an aggregate product speed based on product mix and the speed at which each product is presently manufactured. The 1996 speed adjustments are shown in section 1J of the Production Plan. In the example, product not produced due to speed losses is given as a yearly percentage of theoretical capacity(percent loss).

4.1.4 Capacity Adjustments

Capacity adjustments are the losses from various production parameters that result in the region not achieving revised output levels. The production system yield model provides data to determine the monthly losses. The intention of the capacity adjustments is to reveal to management actionable items that generate capacity losses. By seeing how much capacity is lost by a certain parameter, management can make informed decisions on how to change certain parameters to increase capacity. In Section 1D of the model eight capacity parameters are given. These parameters are: employee absence, holidays, major R&M(repair and maintenance), PM(preventive maintenance), mold equip failures(molding equipment failures), all other downtime, scrap and product losses due to tool shortages. The scrap parameter is comprised of the following subcomponents: scrap at mold, post mold, finishing, off line processing and other. Capacity adjustment parameters are those items that have a significant impact on capacity, have the potential to be altered, and management desires to know the present and future effects of these parameters. Depending on the regions' needs, the parameters that are detailed can be modified. For certain facilities, employee absence may not be a large capacity loss, and this may want to be considered in with product losses due to all other downtime. Presently, product loses from a given parameter are a function of demonstrated unit per time cycle(or present machine operating speeds). Scrap is a function of revised output. As relationship between parameters is more fully understood, equations linking these could be put into the model.

4.1.5 Demonstrated Capacity

Demonstrated capacity is quality sellable output the region can realistically produce given present performance levels. Therefore, Demonstrated Capacity equals Theoretical Capacity minus Speed Adjustments minus Capacity Adjustments. Section 1E shows the monthly and yearly demonstrated capacity for the region and this information will be important in establishing a production plan.

4.1.6 Production/Inventory Plan

The production/inventory plan establishes the amount of useable product(quality sellable product) that will be produced on a monthly basis, and determines what inventory targets are desired. The capacity adjustments section has accounted for the scrapped product that will be produced for the given month. The aggregate sales demand from section 1A is shown again in section 1F as 1995 Demand. The production/inventory plan is given an initial beginning inventory of product and calculates beginning and ending inventory for subsequent months. If a make to order strategy is intended, then inventory targets can be set to zero. Setting inventory targets can be helpful when implementing a make to stock strategy since difference to target shows how many units above or below the stated inventory target were produced in a given month. If the ending inventory is negative, then the demand for the given month was not met. A new production plan could be established but if the excess demonstrated capacity is negative then this shortfall cannot be produced. Excess demonstrated capacity is demonstrated capacity minus production plan useable product. Excess demonstrated capacity needs to be zero or positive at all times for the plan to be feasible. The region can establish an amount of excess capacity that will be carried at all times, allowing them to prepare for unexpected demand. Given variations in demand, desired excess capacity may vary depending on monthly volatility. Also, accounting could assess the cost and benefit tradeoffs of extra inventory and of excess capacity.

4.1.7 Materials Requirements

Materials requirements establishes how much raw material must be received to meet production requirements and scrap allowance. In Section 1G of the model only polymer raw material requirements for molding are presently established. Post-mold processing raw material requirements could be incorporated at a later date. An initial beginning inventory is entered and beginning and ending inventory of polymer is calculated for subsequent months. An inventory target can be set monthly based on the amount of raw material the facility intends to have available at any given time. By setting the inventory target and examining the difference to target number it can be determined if monthly shipments need to be modified. Knowing the amount of usable units that will be produced and using the average weight per unit a calculation determines how much material will be needed for production. Material wasted as scrap can be determined based on anticipated scrap levels, given in the capacity adjustments section. Scrap material that will be recycled is not considered in the material requirements, even though there is a time lag on its use. Entering the intended receipts of material for the month allows the user to determine if the yearly material requirement will be met. If the ending monthly inventory is negative then more material receipts will be needed. To ensure that material ending inventory is zero or positive, the production plan will need to be modified if increasing material receipts is not a feasible option.

4.2 Facilitating Communication

The production planning model incorporates information from various functions of the organization. Some of these functions include: marketing/sales, manufacturing, design/research and development, purchasing and finance. Each function has a role within the organization. The results of the model provide management a mechanism for discussion and information exchange on the important linkage each function has in assisting the organization in meeting its objectives. In order for a feasible production plan and materials requirements to be generated, forecast accuracy and a realistic demonstrated capacity are critical.

The model allows each function to examine the impact of their information and other group information on the present and future organization's ability to meet customer orders. The marketing/sales group interacts with the customer and will provide forecasted demand data for the model. Given historical sales data, as well as industry trends a confidence level can be assigned to the forecast. Based on the forecast, manufacturing will have to determine how many individuals to hire, and purchasing will decide on materials requirements. Manufacturing has data around their performance, and this information will assist in determining a demonstrated capacity. If manufacturing does not deliver the stated demonstrated capacity the implications could include unmet orders or if they exceed the expected demonstrated capacity, there could be excess capacity which was not utilized. The design/research and development group contributes technology advances that assist in increasing demonstrated capacity, as well as establishing new markets. These advances, which can be analyzed with the production planning model, could include a new design, or different materials. The purchasing group needs to know how much raw material to buy and when. Given raw material shortages, the earlier they have material needs the quicker they can ensure availability. Finance is involved because they can state how much does it cost to have a certain excess capacity position, as well as what technology advances make sense from a cost perspective. Also, if ways to increase demonstrated capacity are examined, the finance group can suggest which options are fiscally feasible.

4.3 Base Case

A hypothetical example of a production planning model is shown in Figure 4-2. The 1996 sales were calculated based on 2 percent growth for the industry. The theoretical capacity in 1995 and 1996 is the same, since this region is not expected to add any machinery. The capacity adjustment categories and product losses are listed in Table 4-1.

Capacity Adjustment Category	*Yearly Product Losses (Z Units)*
Speed	11.67
Total Scrap	9.38
Tool Shortages	6.63
Other Downtime	3.31
Holidays	2.97
Equipment Failures	1.16
Repair and Maintenance	0.44
Absences	0.35
Preventive Maintenance	0.3
Total	36.21

Table 4-1: Capacity adjustment categories with corresponding product losses.

Speed, total scrap, other downtime, equipment failures, and repair and maintenance data was obtained from the production system yield model. Tool shortages were established based on comparing demand for a given product profile versus tooling capacity for the product profile. Holidays were obtained from human resource department. Losses due to absences were estimated based on limited absentee data and turnover data. In 1995 this region is starting a new preventive maintenance cycle. As a result of doing testing on a selected group of machines, preventive maintenance schedules will be doubled throughout the region. On the old preventive maintenance cycle yearly product losses due to preventive maintenance were 1.13 z. Losses due to the new cycle are incorporated into the model and these losses are intended to be considerably lower. The demonstrated capacity for 1995 and 1996 are similar. This model does not account for productivity increases in 1996, but this could be achieved by speed increases or improvement in a capacity adjustment parameter. The 1995 demonstrated capacity is 23 percent less than the revised output(output after speed adjustments) and 33 percent less than the theoretical capacity. The region had not established a level of excess demonstrated capacity for the production plan. The goal of the production plan was to meet customer demand every month, and use make to stock strategy if necessary. It was assumed that January 1995 beginning inventory was 0.3 z. In terms of material requirements, polymer is the primary raw material. It is assumed that there is not a limitation on the amount of polymer received every month. The 1995 demand can be met given present capacity, but there is very little excess capacity available during the year. If 1995 demand increases 15 percent every month, starting in June all customer orders will not be met. Figure 4-3 shows the cumulative demonstrated capacity and demand for 1995. When the cumulative demonstrated capacity line is above the demand line all orders can be met, but if the cumulative demonstrated capacity line falls below the cumulative demand line a product shortfall will exist.

As shown in Table 4-1, the top three areas for opportunity to reduce product losses are speed, total scrap, and tooling shortages. A comparison of similar products at different facilities may be done, to see if any speed improvements could be achieved by standardizing product run speeds. As speed losses decrease, the losses that occur in other categories will increase slightly since losses are presently a function of speed. More than half of the scrap losses are due to other scrap losses that are not well defined. If these other scrap losses were reduced this could have a significant impact - not only will more capacity be available, but less material will need to be purchased. Although there are losses due to tooling shortages, if sales can be generated in products where excess tooling is available, additional capacity would be available for use. Also, if the region anticipates that it will be short similar tooling in 1996, a cost benefit analysis should be done to determine if additional tooling should be bought.

4.3.1 Comparison to 1994 Data

Using 1994 information the production planners for the facilities in the region state that demonstrated capacity is 83 z for the 1995 year. The difference between this number and the production planning model demonstrated 1995 capacity of 84 z is small. This difference could be attributed to differences in how losses from capacity adjustment parameters are determined.

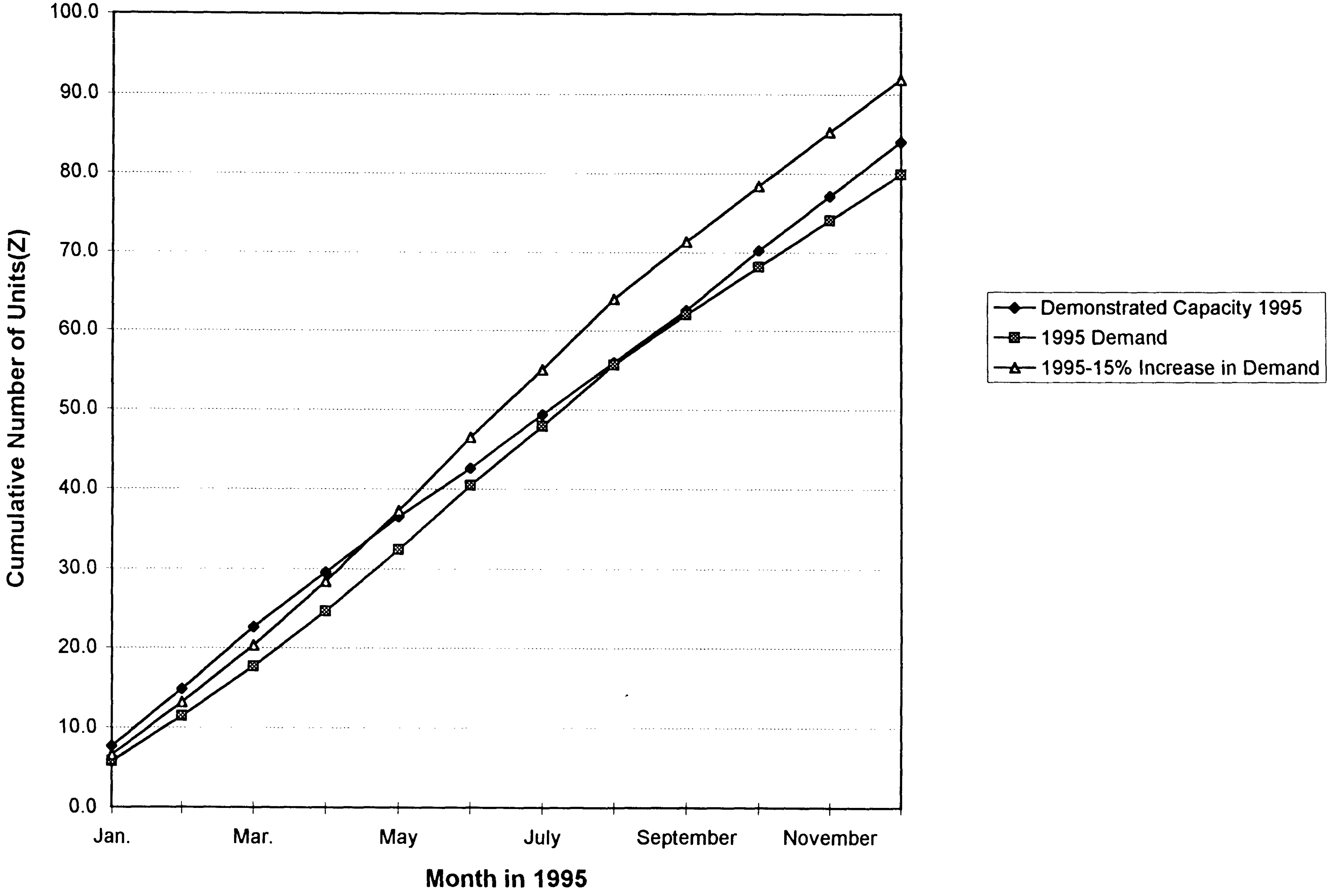

Figure 4-3: Cumulative production information shows that if Demand increases 15% every month that after May demand will not be met.

The 1994 yearly PSY number for each facility in the region can be used to obtain an average PSY for the region of 60 percent. By establishing demonstrated capacity at 33 percent less than theoretical capacity the production planning model suggests that the region has the capability to achieve 67 percent PSY. There are several possible reasons why 67 percent PSY was not attained. In 1994, the region may not have had enough orders, therefore having excess demonstrated capacity during the year. The lower PSY could be a result of a higher product loss due to capacity adjustment parameter downtime being inconsistently recorded. Also, the PSY model takes into account customer returns and inventory obsolescence whereas the production planning model does not include this. If customer returns and inventory obsolescence require production of additional product, then this would result in changes in demand, and the production plan and require additional materials. This information could be incorporated into the model.

4.4 15% Increase In Demand

The production plan will allow management to analyze alternative ways of ensuring that the region can meet a 15 percent increase in demand. Examining two options: adding more machinery, or reducing scrap show that there are tradeoffs to each alternative.

4.4.1 Adding Machinery

Management may want to consider adding more machines to ensure meeting demand. When increasing the number of molders for 1995, the model calculates a new demonstrated capacity and a revised production plan can be created. It was assumed that productivity levels remained the same as in the base case, and machines were added until monthly demand was met. For the region to meet a 15 percent increase in demand without delaying orders, 13 percent additional machines will need to be added to the region. Figure 4-4 shows the ability to meet demand at various demonstrated capacity levels.

All lines below the cumulative 1995-15% Increase in Demand line indicate a shortfall in meeting orders. At the base case(Y machines) the region would be able to meet demand until May, and then a shortfall will be experienced. Even if customers are willing to wait for their orders, by the end of the year there will be a shortfall of 7.6 z. At 1.08Y machines demonstrated capacity, all orders will be met without delay until June. If customers are willing to wait for their orders, then by the end of the year there will be no shortfalls. To ensure no shortfalls at any time during the year, 1.13Y Machines would be needed.

To add 13 percent more molding machines, there would be a major capital expenditure, since this would involve the need to buy some Post-Mold Machines and Finishing Machines so that molding would continue to be the bottleneck operation. Also, additional labor and floor space to put the machines may be needed. In addition, more machines would increase material costs. These costs would have to be weighed against the potential revenue lost. Will customers be willing to wait for their orders? The value of customer good will and future lost sales due to delays are difficult to measure. Table 4-2 shows the potential percentage of revenue lost if customers are not willing to have their orders delayed versus if customers are willing to have their orders delayed. In the base case, even if customers would accept delayed orders, there is a potential loss of revenue of nine percent per year due to insufficient capacity. With eight percent additional machines (1.08Y machine Demonstrated Capacity), all orders will be met if customers accept delays. If customers will not accept delays, there is a potential lost revenue of approximately 2 percent per year.

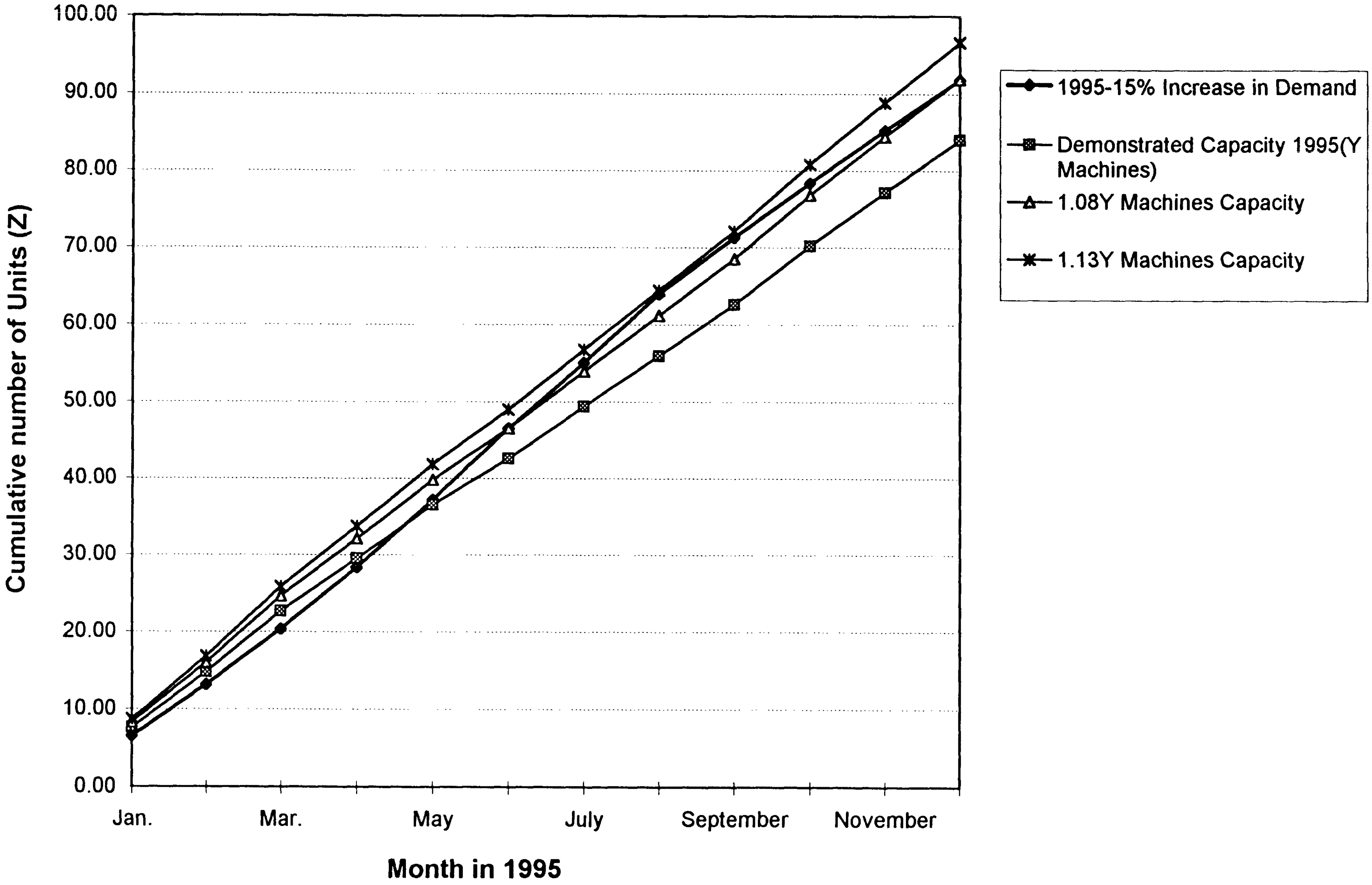

Figure 4-4: In order to meet a demand 15% stronger than expected, given no changes in productivity, 13% more machines would have to be added(total of 1.13Y machines) to the base case to ensure no product shortfalls. *

Number of Machines	Potential Lost Revenue With No Delay Accepted (Percentage/Year)	Potential Lost Revenues With Delay Accepted (Percentage/ Year)	Shortfall Months
Y (Base Case)	10.12%	9.08%	May -December
1.08Y	2.27	0	July-October
1.13Y	0	0	none

Table 4-2: With 1.13Y machines the region will be able to meet all orders without delay if demand increases 15 percent.

Cost of machinery, the value of meeting customer orders on time, and other alternatives to meeting customer orders are all factors that influence a decision to determine if machinery should be added. If meeting customer orders on time is critical, then a certain amount of excess capacity at all times will be desired.

To assess the cost and feasibility of adding machines, a net present value(NPV) and internal rate of return(IRR) calculation was performed.** The company expects a minimum of a 20 percent rate of return on any investments they proceed with. Five additional molding machines and the corresponding Post Mold Processing and Finishing machines would be a significant investment. It was assumed the machinery would be operational immediately after investment and added to an existing facility in the region, where floor space was available. The corporate tax rate is 34 percent and a seven year straight line machinery depreciation schedule was used. If the existing product price, manufacturing cost, throughput rates, and 352 day yearly machine operation of all five machines are maintained, then a net present value analysis of this investment is positive at a 20 percent rate of return for four years of machine use or beyond. The IRR of this

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** NPV is the present value of cash inflows less the present value of cash outflows, or the increase in wealth accruing to an investor when they undertake an investment. IRR is the discount rate at which projects net present value equals zero. Rate at which funds left in a project are compounding(c. f. rate of return or yield obtainable on an asset)[6].

investment at three years of machine use is 11 percent, at four years is 23 percent and at five years is 30 percent. It was assumed that the machinery had no value after it was used for a given duration of time, but if the machinery was able to be sold after it was used than the IRR would increase. If there is a delay between the investment and availability and operation of machinery then IRR will decrease. Machine utilization, productivity improvements, length of time machinery is needed, and expected changes in product price and product manufacturing cost are all key components of evaluating the decision to add machinery.

Adding machinery may result in a decreased or increased price for all product. Figure 4-5 shows the internal rate of return given a percentage change in price for a three, four and five year useful machine life. At a five percent decrease in price only a five year machine use maintains an internal rate of return above 20 percent, and at a ten percent decrease in price, a 20 percent IRR is not met even after five years of machine use. An IRR above 20 percent is obtained for a three year machine life with an increase in price of seven percent or more.

Even if price remains constant, cost fluctuations are possible. Material costs are rising, and at the same time the facility is implementing cost reduction programs to reduce labor. A 10 percent increase in cost results in a marginal internal rate of return of 20 percent over a five year period. Figure 4-6 shows the internal rate of return given a percentage change in cost for a three, four and five year operational period. In order to obtain a 20 percent IRR over a three or four year machine life, costs will have to decrease.

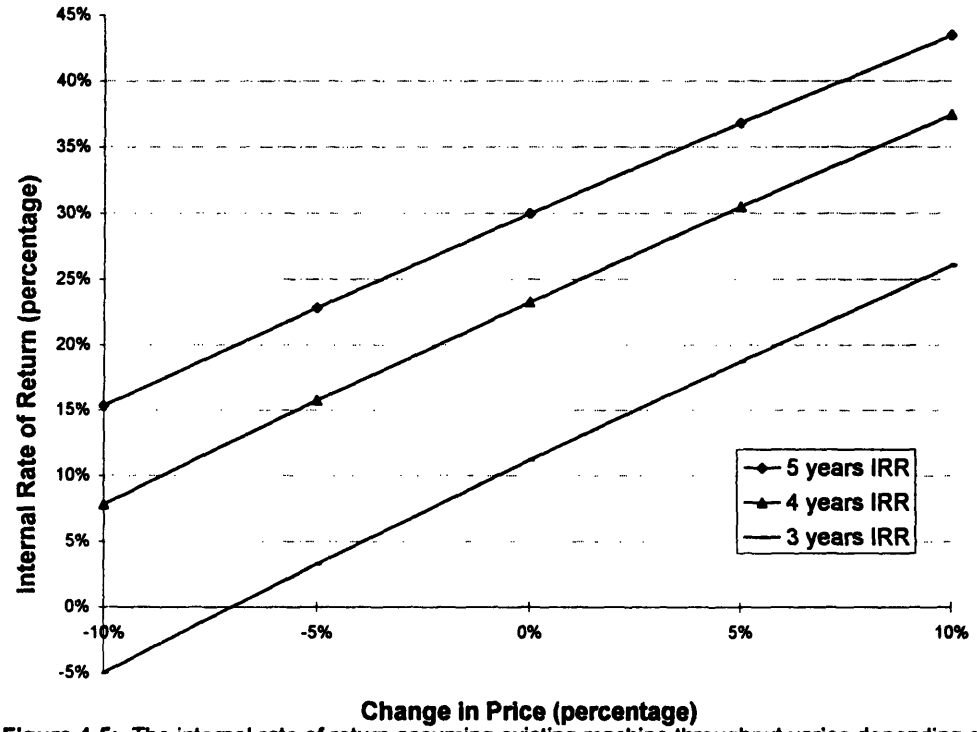

Figure 4-5: The internal rate of return assuming existing machine throughput varies depending on the life of the machine.

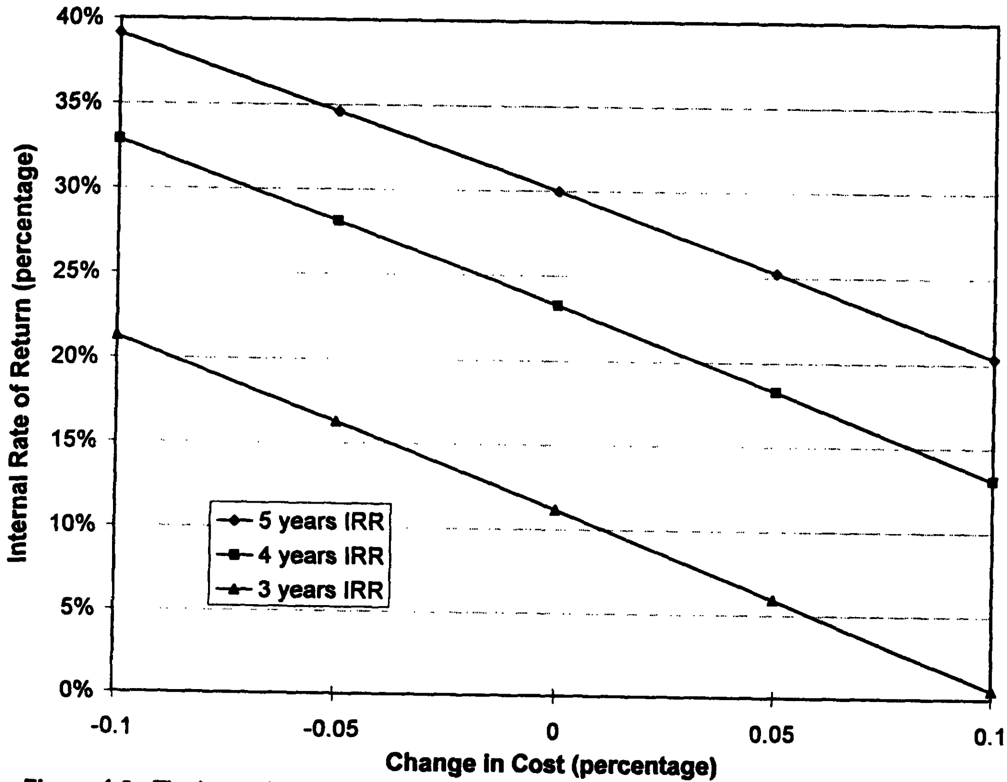

Figure 4-6: The internal rate of return given a percentage change in product cost for a three, four and five year operational period.

If the throughput was increased by productivity improvements, then more product could be produced and sold without increases in labor costs. Figure 4-7 shows that IRR increases as a result of throughput increases. A five percent throughput increase results in a smaller change in IRR than a five percent change in price or cost. If machine utilization was decreased, then internal rate of return would be lowered as shown in Figure 4-8. An 80 percent machine utilization (or four out of five machines used) over the useful life of a machine results in an IRR slightly above 20 percent for a five year machine life.

One way to meet a 15 percent increase in demand is to add machines. Under the right circumstances investing in machinery is a sensible decision. The investment has a positive net present value at 20 percent discount rate given present price, cost and throughput rates. Fluctuations in price, cost, utilization and throughput can change the expected return from such an investment, therefore accuracy and validity of demand forecasts and assumptions are very important. Also, the impact of adding machines on the price and cost structure of the rest of the business needs to be evaluated. If demand is expected to be above regional capacity for several years, and productivity improvements cannot be obtained fast enough, investment in machinery needs to be considered.

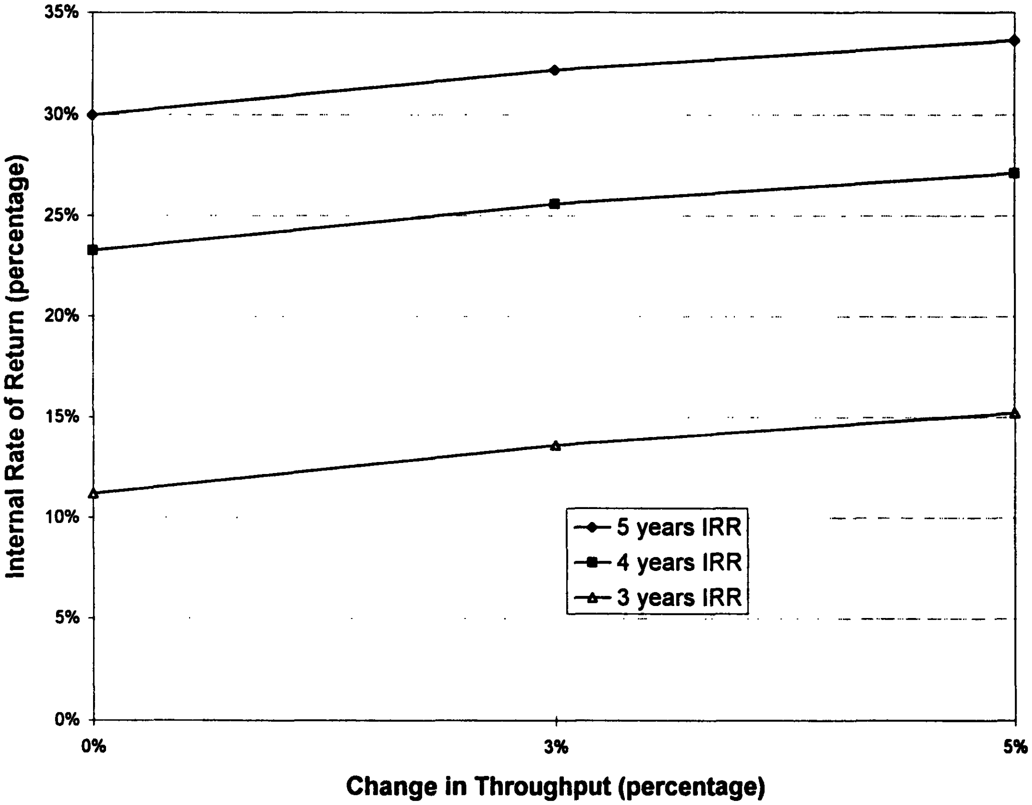

Figure 4-7: An increase in throughput increases the internal rate of return.

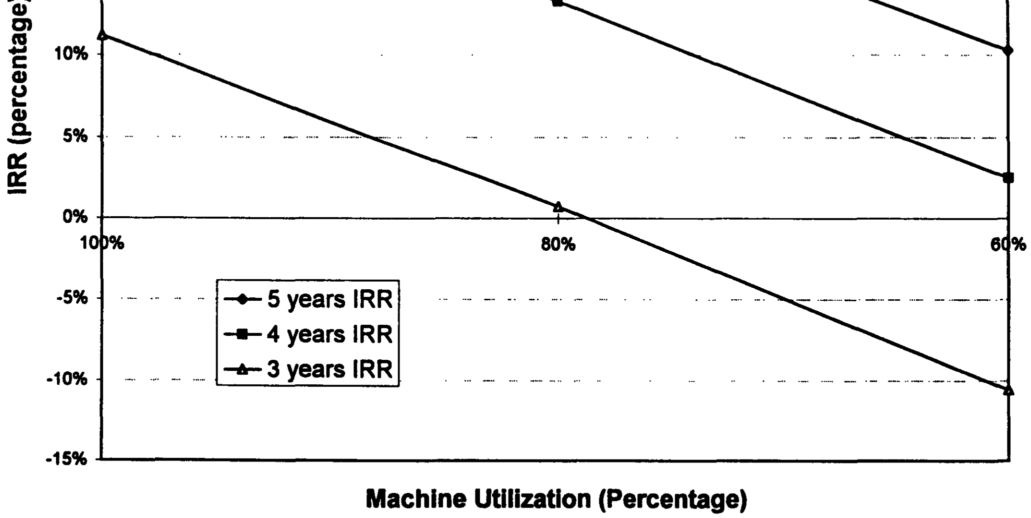

Figure 4-8: A decrease in machinery utlization lowers internal rate of return.

4.4.2 Productivity Improvements

If management feels that there are opportunities for productivity improvements the model can be used to evaluate these alternatives. The region's level of scrap is difficult to precisely measure. The production system yield model calculated a scrap rate that was used in the base case model. The scrap calculations in Chapter 1 suggest that this could be a high rate. The other component of the scrap parameter, scrap the region can not account for, is the majority of the scrap. Using the model it was assumed that all or a fraction of the other component of scrap was eliminated. If all of the other component of scrap was eliminated the result is a 67 percent decrease in total process scrap and a 5 percent increase in capacity. Still, with a 15 percent increase in demand, there would be a shortfall starting in June. Therefore, a 67 percent decrease in scrap alone would not be enough to ensure that all orders would be met on time.

Productivity improvements along with reduction of other capacity adjustment parameters would increase capacity. If all holidays were eliminated, except for three in December, and the 67 percent decrease in scrap was achieved this combined would be equal to adding five machines worth of capacity during the year. Therefore the lost revenues are similar to those given in Table 4-2 for 66 Machines, or approximately two percent of revenue lost if customers do not accept delays. Also reducing scrap would result in a materials saving that could be substantial. The region will need to determine if it is possible to eliminate holidays, and if this is cost effective. Loss of holidays may lower employee morale. Also, the region will need to determine if productivity improvements, such as scrap reduction are feasible.

4.4.3 Comparison of Alternatives

Table 4-3 shows the tradeoff of a variety of alternatives that would allow some fraction of the increase in demand to be met.

Scenario	**Costs**	**Orders Missed/Delayed**	**Yearly Material Used**
Base Case (Y Machines)	cost of missing and delaying orders	May -Dec. delays 7.6 z missed	Production: 72.73 Wasted as Scrap: 7.21
1.13Y Machines	Capital costs-buy machinery additional labor add floor space material costs	none missed or delayed	Production: 79.67 Wasted as Scrap 8.16
1.08Y Machines	same as 69 Machine scenario plus cost of missing and delaying orders	July-Oct. delays	Production: 79.67 Wasted as Scrap: 7.8
Reduce Scrap 67% (Y Machines)	improvement costs* cost of missing and delaying orders	June-Dec. delays 0.8 z missed	Production: 77.85 Wasted as Scrap: 2.23
Reduce Scrap 67%+only 3 Holidays (Y Machines)	improvement costs* and holiday pay cost of missing and delaying orders	July-Oct. delays	Production: 79.67 Wasted as Scrap: 2.23

*Improvement costs may include cost of training individuals in new techniques, cost of designed experiments, cost of improved measurement devices or equipment devices so that productivity gain could be realized.

Table 4-3: Increasing number of machines and maintaining productivity levels increases scrapped material while orders will still be missed if productivity improvements in scrap occur but scrapped material will be reduced.

If the region has a limited polymer raw material supply, certain options are more appealing than others. If the scenario allows all of the 15 percent increase in demand to be produced on time or by delaying orders, with 0.4 z inventory of product in December, then 79.67 million pounds of polymer is needed for yearly production of salable product. The amount of material that will be produced as scrap varies depending on number of machines, since scrap is a percentage of machine output. Decreasing scrap considerably reduces the amount of material that will not be able to be used.

There are tradeoffs to adding additional machines to meet demand versus achieving productivity improvements. Additional machines are costly, but capacity gains can be realized in a short period of time, given that there is space, machines can be purchased when needed and trained labor is available. Also, more machines will allow potential excess demonstrated capacity. When evaluating the reduction of scrap using the model it was assumed that scrap was decreased in the beginning of 1995. Productivity improvements take time and have learning curves associated with them, therefore assuming that scrap rates would be decreased across the board may need to be modified to better account for learning curves. Depending on the manufacturing strategy a combination of adding machines and productivity improvements may make sense. Productivity improvements, such as reducing scrap, are generally lower cost solutions to increasing capacity than adding machinery.

4.5 Other Production Planning Scenarios

The production planning model can assist management in examining projects that will affect capacity in the future. The model will allow the region to determine if the timing of the project is correct. The project may be great, but it may have had a larger impact if it was implemented earlier, or the model may show that the timing will meet the needs of the organization.

4.5.1 Implementation of New Product Design

Due to market demands calling for a product with superior functional performance the design group is planning to implement a new product design starting in April 1995. Implementation will be complete in June 1995. The new product will assist in improving manufacturing speeds, and has been designed with the intention of design for manufacturability. Other benefits of the new design include reduced tooling shortages since it will be a substitute for an existing product profile and lower scrap rates, since the new design is intended to process less defective caps. This new design affects between 10 -20 percent of the product mix. The newer speeds were put into the production planning model. Data on improved defect levels and effects on tooling were not available, therefore these numbers were unchanged. The new design production planning model can be found in the appendix. Speed losses were reduced by two percent for the year 1995, resulting in a two percent increase in demonstrated capacity. All orders were met in 1995 and a 0.1 z excess demonstrated capacity was maintained, or slightly greater than one percent of demonstrated capacity. In 1996, a 0.2 z excess demonstrated capacity was able to be maintained. If demand increased 15 percent in 1995 all orders would not be met after the month of June, but implementing the new product does allow the facility to produce 1.6 z more product than the base case.

4.6 Limitations of Production Planning Model

The production planning model is an effective tool at revealing product losses, providing production levels and materials requirements, but a framework for analysis of the model will need to be customized by the company. As a company, business philosophy and strategy will determine how certain scenarios the model provides are analyzed. What priority is material conservation and meeting customer orders on time? These decisions will influence the recommended material safety stocks and demonstrated excess capacity that is desired when using the model. A make to order strategy may require longer lead times in peak season. Starting the year with a given amount of excess capacity may be costlier than none, but will allow more flexibility when order load varies unexpectedly.

The assumptions used to create the model will affect the production information. Once a regional production plan is established, and tradeoffs of various management decisions are examined, the next step is implementing a regional plan at the facility level. Although the facilities were involved in providing information for the production planning model, disaggregating the demand and production plan can be challenging depending on the assumptions. One facility may be required to make certain product due to in country manufacturing requirements or customer preference. In the production planning model, where possible, aggregate planning attempted to take into account losses created due to product mix and tooling shortages. Product mix and scheduling issues can create difficulties in achieving the intended production plan.

The model does not take into consideration costs. Price is a factor for competitiveness, therefore costs are key. If cost reductions are made, such as reducing labor (but this decision does not affect productivity and or materials requirements), then the model will not be useful in evaluating this decision. Profitability of product lines will need to be examined, especially if certain customers will be turned away due to insufficient capacity. To improve a region's ability to meet demand, could certain orders be subcontracted out by buying a competitor's capacity versus adding capacity?

The production planning model can be effective in establishing aggregate levels of production. Several scenarios were shown to indicate various ways the model could be used as a tool. It can provide information on: demonstrated capacity, ability to meet forecasted demand, ability to meet increases in demand with productivity improvements or by adding machinery, provide production and material information for a cost analysis and evaluate the effects of technology/machinery advances. It is a good tool for making broad decisions, and to help foster communication between various functions of the organization. For this to be an effective tool, accurate data needs to be inputted. Planning on a facility level will still need to be done. Variations between the regional aggregate model and the facility level include tool shortages, as well as product mix. Other variations will need to be identified and evaluated.

Chapter 5: Conclusions And Recommendations

5.1: Conclusions

The objective of this thesis was to develop and demonstrate a framework for production planning and productivity improvements. Several tools were recommended to address the inconsistent measurement system, raw material shortages, and insufficient capacity issues that are presently occurring at the molding facilities. These tools included the PSY model, Production Planning model, and an increased quality control focus. Used together these tools provide the facilities with a proactive approach to addressing how to meet customer demand, and increase capacity. Management's use of PSY and Production Planning will allow the facilities to have a baseline measure of initial capabilities and how this translates into effective execution of meeting customer orders. These tools provide an information platform to set direction and focus for continuous improvement efforts.

Continuous improvement and proactive planning provide assistance in meeting customer requirements, as shown in Figure 5-1. Raw material can affect quality, constrain capacity, and influence productivity gains. Therefore, material measurement and control is important in reducing process variation. In addition, consistent and accurate data reporting are key in evaluating capacity capabilities and measuring productivity gains. Customer loyalty and good will are dependent on facility responsiveness to customer demand. By considering capacity tradeoffs to maximize customer satisfaction, increased quality product to the customer can be achieved, and this will effectively result in increased profitability.

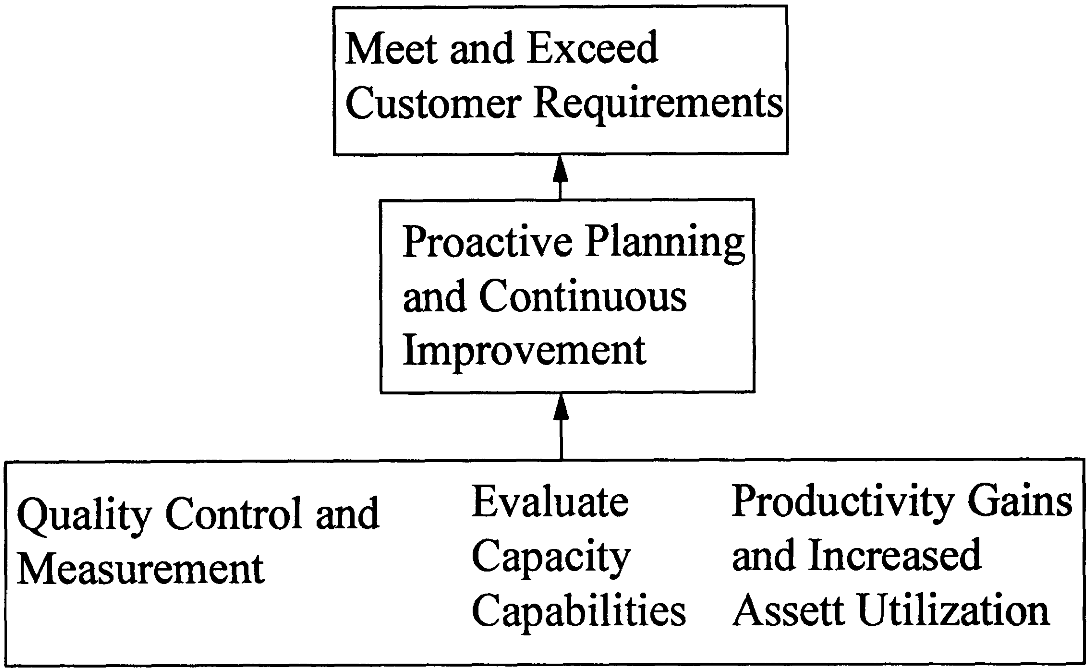

Figure 5-1: A proactive improvement effort enhances a company's ability to meet customer requirements.

PSY is a measurement tool used to standardize production performance measures across facilities. The model also concentrates on increasing facility utilization by prioritizing which of five major factors to examine. Scheduled Time factor, is an area that provided the greatest opportunity for capacity increase. The Pareto charts and run charts set up a uniform method of tracking and categorizing data across facilities. Common metrics are established which assist in providing agreement on definitions of measures and a mechanism to ensure accuracy of information. The model helps determine what data to pursue to assist in discovering the root cause of problems. By illustrating discrepancies between reported and calculated measures, such as scrap, the model increases awareness of the need for accurate measures. Comparing the same product produced at separate facilities assists in establishing standard measures.

Production planning model is a tool for management to evaluate the impact of demand fluctuations and productivity improvements on production plans and materials requirements. This spreadsheet tool assists in fostering increased communication between business unit functions, therefore providing management with information to make more informed decisions at a regional level. Also, providing management with the opportunity to determine where product losses are occurring lets them establish programs to address these losses.

Both of these tools suggest that reductions in internal process scrap will provide increases in capacity. As the product has more value and cost added to it during processing, it is imperative that it will not be scrapped. To verify that suppliers have sent material within specification, increased inspection of incoming raw material is recommended, which could include visual as well as melt flow and other tests. Narrowing melt flow specifications will help to reduce process variation. Process variation results in defects that can cause internal process scrap or customer returns. Customer returns are more costly than internal process scrap, and generally need to be reproduced. Minimizing internal process scrap will help increase capacity. A 67% decrease in calculated internal process scrap for a region results in a 5% capacity increase. Also, the estimated scrap rate at one facility results in potential lost revenue of six percent, and wasted material. During a period of raw material shortages, recycling of raw material provides cost savings, and more effective material usage. Weighing scrap and relating scrap back to the root cause or process it occurred at will increase accuracy, help to determine where to alleviate scrap and facilitate improved material usage. Also, the ability to verify the amount of material received will assist in quantifying all material usage.

Planning and linking quality and measurement control with planning, will help to meet manufacturing strategy and to allow manufacturing to be seen as a competitive advantage within the organization. Quality improvements will assist in several areas. The value of systems such as production planning and production system yield is that they allow management to determine where to focus for possible capacity increases. One thing that must be kept in mind when using these tools is how improvement efforts affect value added processes. The positive results of standardization is that it attempts to provide consistency within the organization, in order to leverage capacity and resources. When measurement processes are implemented it is important to determine data collection requirements on what to measure and to not overwhelm individuals with data so that time and effort are spent analyzing data that reports information about the status of the process.

These tools create value in several ways. The PSY model shows additional data to address the root cause of problems that are interfering with higher facility utilization. The Production Planning shows how improvements affect ability to meet customer orders. The models can illustrate the value of productivity gains, but management must implement the productivity gains. Also, the amount of delays or missed orders are revealed as well as the major capacity parameters that contributed to not being able to meet orders. If a competitor can meet a customer's order on time, the customer may not accept delayed orders or may not return in the future if orders were missed. In addition, customer returns not only impact scrap and materials usage, but potentially affect future orders. Therefore, successfully implementing these tools will provide the molding facilities with tools to learn about the impact of certain options on ability to meet customer orders as well as ways to resolve issues that are lowering theoretical capacity. Investing in additional machines is a method for increasing capacity and being able to meet demand volatility if productivity improvements can not be achieved. A strategy that adds machines, increases productivity or both, needs to be planned in advance and then implemented and monitored. Updating and continuing to use these models allows management to track and modify strategy if necessary.

There is a tradeoff in cost, time and material usage between increasing capacity by investing in machinery versus investing in productivity improvements. The facilities may lose orders forever if capacity is not in place. Management needs to decide if and how customer orders will be met, and tools such as those mentioned can assist in the decision. It is difficult to value the cost of a lost opportunity. The tools discussed will assist management in establishing methods to meet as many customer orders as possible. These methods may include a combination of buying machinery and productivity improvements. The real gain that the tools provide is that since they are customized to the facilities and regional markets they serve, as the issues change or more accurate data is available, the models can be quickly adapted and updated if need be to measure other parameters and exact results and information in appropriate areas.

5.2 Recommendations For Future Work

Continuous improvement efforts to increase quality and productivity and production planning efforts to decrease delayed or missed orders are dependent on management's timely access to and analysis of accurate data and their ability to implement methods that assist the organization in profitably meeting orders. The following recommendations would enhance implementation and usage of the production system yield model, the production planning model, quality measurement and control efforts and other strategic tools:

- Accelerating and broadening the quality effort will result in increases in productivity in several areas within the organizations. A study on quality benefits would be helpful in specifying the tangible as well as intangible benefits. Tracking and monitoring must be done to produce improvements. Management should consider increasing quality to a point where facilities can share resources.
- Forecasting affects the ability for manufacturing to plan and effectively execute the plan. It has been stated that customers really do not know their demand. Identifying tools and techniques that can be implemented will allow this organization to better understand the customers' requirements. In addition, historical trends and cost benefit analysis, will assist in establishing guidelines which indicate the desired levels of regional and facility demonstrated capacity and product inventory.

- For effective implementation of a measurement control system, commitment to quality improvement is required. An organizational analysis that examines the metamorphosis that the facility undergoes can be documented. As the organization experiences change, it will be critical for staff at all facilities to embrace these measurement control and quality tools. Transfer of knowledge between facilities regarding best operating practices can assist in increasing quality levels. In addition, standard product operating procedures for all facilities will increase the value of common metrics.

- There are information resources that enable the facilities to learn from the machinery group that produces the equipment. Additional benefits can be gained by increased interaction between machinery and product manufacturing operations. Studying and understanding the competitive advantage held by the molding division by producing their own equipment will improve manufacturing policies and productivity.

In conclusion, this thesis has focused on the importance of tools to improve raw material and manufacturing measurement and quality, and production planning. By achieving productivity improvements, capacity can be increased without investing in machinery. If improvements can not be gained fast enough, then an alternative method of meeting all valued customer orders needs to be implemented. The production planning model, the production system yield model and quality improvement efforts provide a framework for management to evaluate and prioritize manufacturing decisions.

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Appendix

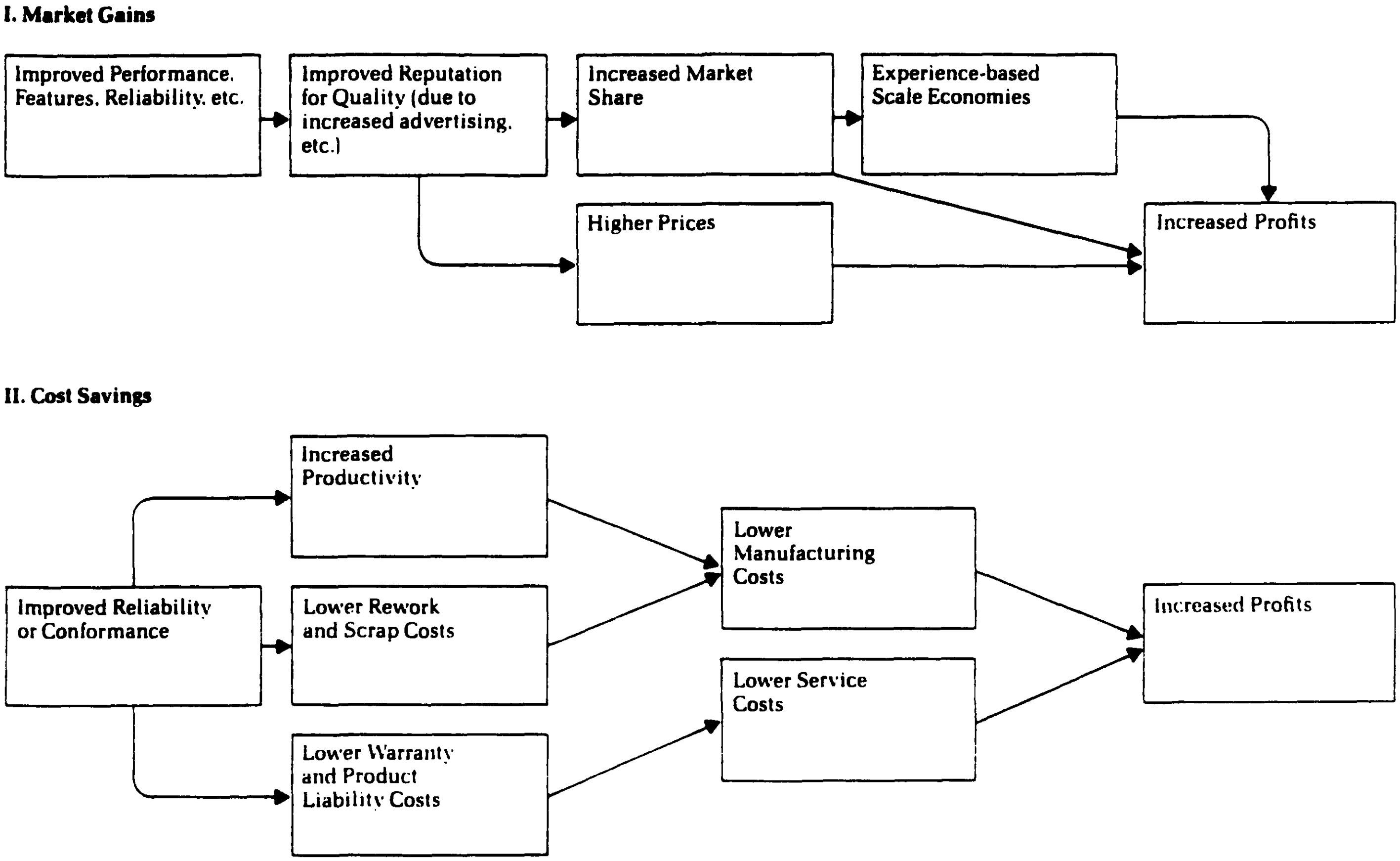

Figure A-1: Garvin's analysis of quality and profitability.

		Production Planning -z units											
	Demand	Management Array											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1A: Aggregate Sales													
1995	5.70	5.71	6.26	6.97	7.71	8.07	7.43	7.80	6.35	6.14	5.97	5.74	79.85
1995-15%	6.55	6.57	7.20	8.01	8.87	9.28	8.55	8.97	7.31	7.06	6.87	6.60	91.83
1996	5.81	5.83	6.39	7.11	7.86	8.23	7.58	7.95	6.48	6.27	6.09	5.85	81.45
1B: Theoretical Capacity													
1995													
Number of Molders	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
Number of days per Month	31	28	31	30	31	30	31	31	30	31	30	31	365
Output- % Theoretical Capacity	100	100	100	100	100	100	100	100	100	100	100	100	
Output	10.21	9.22	10.21	9.88	10.21	9.88	10.21	10.21	9.88	10.21	9.88	10.21	120.23
1996													
Number of Molders	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
Number of days per Month	31	28	31	30	31	30	31	31	30	31	30	31	
Output- % Theoretical Capacity	100	100	100	100	100	100	100	100	100	100	100	100	
Output	10.21	9.22	10.21	9.88	10.21	9.88	10.21	10.21	9.88	10.21	9.88	10.21	120.23
1C: Speed Adjustments 1995													
1995-Demonstrated %	90.0	90.0	90.0	91.1	91.6	92.5	92.5	92.5	92.5	92.5	92.5	92.5	
Molder Speed Loss-UPC	52.4	52.4	52.4	47.7	44.9	40.2	40.2	40.2	40.2	40.2	40.2	40.2	
Product Loss due to Speed	1.0	0.9	1.0	0.9	0.8	0.7	0.8	0.8	0.7	0.8	0.7	0.8	9.8
Revised Output	9.2	8.3	9.2	9.0	9.4	9.1	9.5	9.5	9.1	9.5	9.1	9.5	110.4
											Percent loss		8%
1D: Capacity Adjustments													
1995													
Lost Production Time													
Employee Absence- hrs.	145	145	145	145	145	145	145	145	145	145	145	145	
Product Losses due to Abs.	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.36
Holidays	1	0	0	1	1	0	1	0	1	0	2	3	10
Product loss due to Holidays	0.30	0.00	0.00	0.30	0.30	0.00	0.30	0.00	0.30	0.00	0.61	0.91	3.03
Major R&M-Mach Days Down	15	0	15	0	15	0	15	0	15	0	15	0	90
Product losses due to R&M	0.07	0.00	0.07	0.00	0.07	0.00	0.07	0.00	0.07	0.00	0.07	0.00	0.45
PM Machine Days Lost	5.09	5.09	5.09	5.09	5.09	5.09	5.09	5.09	5.09	5.09	5.09	5.09	61.05
Product losses due to PM	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.30
Molding Equip Failures in Hrs	474	474	474	474	474	474	474	474	474	474	474	474	
Prod losses due to Equip. Fail.	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	1.17

Appendix 1: This production planning model examines the impact of a new product design.

All Other Down time-Hrs	1357	1357	1357	1357	1357	1357	1357	1357	1357	1357	1357	1357	
Prod losses due to All Other	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	3.36
Scrap(7.9%)													
% Due to Mold	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	
Prod losses due to Mold	0.11	0.10	0.11	0.11	0.12	0.11	0.12	0.12	0.11	0.12	0.11	0.12	1.36
% Due to Post-Mold	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	
Prod losses due to Post Mold	0.08	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.97
% Due to Finishing	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	
Prod losses due to Finishing	0.05	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.57
% Due to Inside Finish	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	
Prod losses due to Inside Finsh	0.07	0.06	0.07	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.79
% Due to Other	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	
Prod losses due to Other	0.49	0.44	0.49	0.48	0.50	0.48	0.50	0.50	0.48	0.50	0.48	0.50	5.85
Total Scrap	0.80	0.72	0.80	0.78	0.81	0.79	0.82	0.82	0.79	0.82	0.79	0.82	9.53
Prod Losses due to tool short	0	0.063	0	0.579	0.631	1.654	0.85	1.425	0.714	0.374	0.072	0.268	6.63
Total losses By Month	1.59	1.21	1.30	2.09	2.25	2.88	2.48	2.68	2.32	1.63	1.98	2.44	24.84
										Percent Loss=			23%
1E: Demonstrated Capacity	7.63	7.12	7.92	6.92	7.11	6.27	6.97	6.77	6.83	7.82	7.16	7.02	85.54
1F: 1995 Prod/Inventory Plan													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Beginning Inventory	0.30	2.20	3.59	5.22	5.06	4.35	2.38	1.74	0.45	0.59	1.95	2.88	
1995 Demand	5.70	5.71	6.26	6.97	7.71	8.07	7.43	7.80	6.35	6.14	5.97	5.74	79.85
Production Plan-Useable Units	7.60	7.10	7.90	6.80	7.00	6.10	6.80	6.50	6.50	7.50	6.90	6.70	83.40
Ending Inventory	2.20	3.59	5.22	5.06	4.35	2.38	1.74	0.45	0.59	1.95	2.88	3.85	
Inventory Target	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	
Difference to Target	-0.80	0.59	2.22	2.06	1.35	-0.62	-1.26	-2.55	-2.41	-1.05	-0.12	0.85	
Excess Demonstrated Capacity	0.03	0.02	0.02	0.12	0.11	0.17	0.17	0.27	0.33	0.32	0.26	0.32	2.14
1G: Polymer Requirements in MM lbs													
Beginning Inventory	0.50	0.30	0.59	0.13	0.64	0.95	2.05	2.53	3.27	4.02	2.89	2.30	
Production Requirement	6.59	6.15	6.85	5.89	6.07	5.29	5.89	5.63	5.63	6.50	5.98	5.81	72.30
Wasted as Scrap	0.61	0.55	0.61	0.60	0.62	0.61	0.63	0.63	0.61	0.63	0.61	0.63	7.33
Receipts	7	7	7	7	7	7	7	7	7	6	6	6	81
Ending Inventory	0.30	0.59	0.13	0.64	0.95	2.05	2.53	3.27	4.02	2.89	2.30	1.87	
Inventory Target	1	1	1	1	1	1	1	1	1	1	1	1	
Difference to Target	-0.70	-0.41	-0.87	-0.36	-0.05	1.05	1.53	2.27	3.02	1.89	1.30	0.87	
										Total Needs less receipt			$ (1.37)

Appendix 1: This production planning model examines the impact of a new product design.

1H: 1995- 15% Prod/Inventory Plan													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Beginning Inventory	0.30	1.35	1.88	2.57	1.46	-0.31	-3.29	-4.83	-7.00	-7.51	-6.77	-6.44	
1995-15% Demand	6.55	6.57	7.20	8.01	8.87	9.28	8.55	8.97	7.31	7.06	6.87	6.60	91.83
Production Plan-Useable Units	7.6	7.1	7.9	6.9	7.1	6.3	7.0	6.8	6.8	7.8	7.2	7.0	85.5
Ending Inventory	1.3	1.9	2.6	1.5	-0.3	-3.3	-4.8	-7.0	-7.5	-6.8	-6.4	-6.0	
Inventory Target	3	3	3	3	3	3	3	3	3	3	3	3	
Difference to Target	-1.65	-1.12	-0.43	-1.54	-3.31	-6.29	-7.83	-10.00	-10.51	-9.77	-9.44	-9.03	
Excess Demonstrated Capacity	0.03	0.02	0.02	0.02	0.01	-0.03	-0.03	-0.03	0.03	0.02	-0.04	0.02	0.04
1I: Polymer Requirements in MM lbs													
Beginning Inventory	0.50	0.30	0.59	0.13	0.55	0.77	1.70	2.01	2.49	2.98	1.59	0.74	
Production Requirement	6.59	6.15	6.85	5.98	6.15	5.46	6.07	5.89	5.89	6.76	6.24	6.07	74.12
Wasted as Scrap	0.61	0.55	0.61	0.60	0.62	0.61	0.63	0.63	0.61	0.63	0.61	0.63	7.33
Receipts	7	7	7	7	7	7	7	7	7	6	6	6	81
Ending Inventory	0.30	0.59	0.13	0.55	0.77	1.70	2.01	2.49	2.98	1.59	0.74	0.05	
Inventory Target	1	1	1	1	1	1	1	1	1	1	1	1	
Difference to Target	-0.70	-0.41	-0.87	-0.45	-0.23	0.70	1.01	1.49	1.98	0.59	-0.26	-0.95	
										Total Needs less receipt			0.4524
1J: Speed Adjustments 1996													
1996-Demonstrated %	92.5	92.5	92.5	92.5	92.5	92.5	92.5	92.5	92.5	92.5	92.5	92.5	
Molder Speed Loss-UPC	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	
Prod. Loss due to Speed	0.76	0.69	0.76	0.74	0.76	0.74	0.76	0.76	0.74	0.76	0.74	0.76	8.95
Revised Output	9.45	8.54	9.45	9.15	9.45	9.15	9.45	9.45	9.15	9.45	9.15	9.45	111.28
											Percent loss		7%
1K: Capacity Adjustments													
1996													
Lost Production Time													
Employee Absence- hrs.	145	145	145	145	145	145	145	145	145	145	145	145	
Prod. Losses due to Abs	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.36
Holidays	1	0	0	1	1	0	1	0	1	0	2	3	10
Prod loss due to Holidays	0.30	0.00	0.00	0.30	0.30	0.00	0.30	0.00	0.30	0.00	0.61	0.91	3.05
Major R&M-Mach Days Down	15	0	15	0	15	0	15	0	15	0	15	0	90
Prod losses due to R&M	0.07	0.00	0.07	0.00	0.07	0.00	0.07	0.00	0.07	0.00	0.07	0.00	0.45
PM Machine Days Lost	5.09	5.09	5.09	5.09	5.09	5.09	5.09	5.09	5.09	5.09	5.09	5.09	61.05
Prod losses due to PM	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.31
Molding Equip Failures in Hrs	474	474	474	474	474	474	474	474	474	474	474	474	
Prod losses due to Equip. Fail.	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	1.18
All Other Down time-Hrs	1357	1357	1357	1357	1357	1357	1357	1357	1357	1357	1357	1357	
Prod losses due to All Other	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	3.39

Appendix 1: This production planning model examines the impact of a new product design.

Scrap(7.9%)													
% Due to Mold	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	
Prod losses due to Mold	0.12	0.10	0.12	0.11	0.12	0.11	0.12	0.12	0.11	0.12	0.11	0.12	1.37
% Due to Post-Mold	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	
Prod losses due to Post Mold	0.08	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.98
% Due to Finishing	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	
Prod losses due to Finishing	0.05	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.57
% Due to Inside Finish	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	
Prod losses due to Inside Finish	0.07	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.80
% Due to Other	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	
Prod losses due to Other	0.50	0.45	0.50	0.48	0.50	0.48	0.50	0.50	0.48	0.50	0.48	0.50	5.90
Total Scrap	0.82	0.74	0.82	0.79	0.82	0.79	0.82	0.82	0.79	0.82	0.79	0.82	9.61
Prod Losses due to tool short	0.00	0.06	0.00	0.58	0.63	1.65	0.85	1.43	0.71	0.37	0.07	0.27	6.63
Total losses By Month	1.63	1.24	1.33	2.11	2.26	2.88	2.48	2.68	2.32	1.63	1.98	2.44	24.98
										Percent Loss=			22%
1L: Demonstrated Capacity	7.82	7.30	8.12	7.04	7.19	6.27	6.97	6.77	6.83	7.82	7.16	7.02	86.30
1M: 1996 Prod/Inventory Plan													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Beginning Inventory	3.85	5.63	6.91	8.42	8.11	7.24	5.11	4.33	2.98	3.10	4.43	5.34	
1996 Demand	5.81	5.83	6.39	7.11	7.86	8.23	7.58	7.95	6.48	6.27	6.09	5.85	81.45
Production Plan-Useable Caps	7.6	7.1	7.9	6.8	7	6.1	6.8	6.6	6.6	7.6	7	6.8	83.9
Ending Inventory	5.63	6.91	8.42	8.11	7.24	5.11	4.33	2.98	3.10	4.43	5.34	6.29	
Inventory Target	3	3	3	3	3	3	3	3	3	3	3	3	
Difference to Target	2.63	3.91	5.42	5.11	4.24	2.11	1.33	-0.02	0.10	1.43	2.34	3.29	
Excess Demonstrated Capacity	0.22	0.20	0.22	0.24	0.19	0.17	0.17	0.17	0.23	0.22	0.16	0.22	2.40
1N: Polymer Requirements in MM lbs													
Beginning Inventory	0.50	0.28	0.56	0.09	0.58	0.89	1.99	2.47	3.12	3.79	2.57	1.90	
Production Requirement	6.59	6.15	6.85	5.89	6.07	5.29	5.89	5.72	5.72	6.59	6.07	5.89	72.73
Wasted as Scrap	0.63	0.57	0.63	0.61	0.63	0.61	0.63	0.63	0.61	0.63	0.61	0.63	7.39
Receipts	7	7	7	7	7	7	7	7	7	6	6	6	81
Ending Inventory	0.28	0.56	0.09	0.58	0.89	1.99	2.47	3.12	3.79	2.57	1.90	1.38	
Inventory Target	1	1	1	1	1	1	1	1	1	1	1	1	
Difference to Target	-0.72	-0.44	-0.91	-0.42	-0.11	0.99	1.47	2.12	2.79	1.57	0.90	0.38	
										Total Needs less receipt			$ (0.88)

Appendix 1: This production planning model examines the impact of a new product design.