ABSTRACT

AUDITING & MEASURING THE NEED FOR FLEXIBILITY IN A MANUFACTURING FACILITY

by
Kartika-Sari Stroman

Flexible manufacturing was created out of the need for facilities to be able to efficiently respond to changes in their environment so as to build a competitive advantage. Flexible manufacturing (FM) is currently viewed as a way for facilities to be able to introduce and produce multiple products quickly and more efficiently. In this research we will present some new tools to help managers address the changes that are affecting the facility.

An audit was developed to help system designers identify the changes that are impacting the facilities. The audit provides the opportunity to understand the changes that are occurring and provides an avenue for participants to be able to rank and prioritize the changes that are impacting the facility. The second part of the audit will categorize the changes into one of five areas of flexibility, such as machine, process, product, routing and volume. The audit helps designers identify solutions to address the changes and pre-determine acceptable performance measures for the solutions. This is accomplish by asking a series of questions that allows the designers to evaluate their current system and to determine their ideal system. The later part of the thesis will be used to generate general necessity measures for the machine, process, product, routing and volume flexibility.

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This thesis is dedicated with love to my
family and friends.

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CHAPTER 1

INTRODUCTION

1.1 Problem Description

Manufacturing companies are constantly experiencing change, both in their internal operations and in the outside environment. The ability of a company to efficiently respond to these changes, will determine their competitive position. It is thus necessary that operation managers have a better understanding of the various strategic views of manufacturing flexibility. The majority of operation managers and leaders view flexible systems of production as a competitive advantage and an essential technology to their future success. Therefore, decision makers and leaders of operations have a great need for research in the strategic and operational aspects of flexible manufacturing systems.

It is important that the system designers understand what changes are occurring in their facility and the reason for these changes. Understanding what the changes are, allows facilities to apply the appropriate follow-up or action steps. Understanding why the changes are occurring, helps operation leadership understand the importance and urgency of the changes. An equally compelling issue, deals with leadership's ability to manage the changes or uncertainties that are occurring in the market and within their facility. Operation ` generally agrees that there are a variety of methods, including production equipment, product design, work organization, planning and control procedures, materials management and information technology that are available to meet the needs of flexibility Gerwin (1993). However, the issue at hand is understanding and the know how on how to balance these techniques in an effective manner. Clearly, as of now, there is the no consensus on how to manage those techniques simultaneously. Nonetheless, industry leaders know that this can be accomplish, after all, there are currently some Japanese manufacturing facilities that are proving this.

In the past, American industries viewed flexibility as an adaptive measure to meet customers demand Guptal and Goyal (1989). Some researchers suggest that American industries should try to be proactive in redefining market fluctuations. Gerwin (1993) argues that a facility can encourage customers to see the benefits of shorter lead items and more frequent new product introductions, while providing higher levels of service through superior manufacturing flexibility. Thus, forcing competitors to deal with the changes that the flexible facility has created as oppose to the fluctuation of the market. The changes that a flexible facility can create, could potentially result in controlling market trends. A flexible facility could offer a variety of products, introduce new products quicker, better quality and deliver more cost effective products. As a result, other facilities who are not flexible will not be able to respond as quickly and ultimately will have to play catch-up. Mean while, the flexible facility will continue to introduce a variety of products for customers to select from. Over time, this could possibly result in a competitive advantage for the flexible facility.

1.2 Problem Statement

There is a need for a methodology to determine and understanding what type of changes a manufacturing is experiencing, and then to evaluate the needed flexibility. Competitiveness has resulted in an environment that dictates manufacturing facilities to be able to deliver more new products quicker, more efficiently and more cost effectively. This new methodology will support system designs in efforts to build better flexible manufacturing (FM) facilities.

1.3 Research Objectives

The general objective of this thesis is to develop tools in support of the FM design process. Specific research objectives are as follow: 1) Analyze the changes that a manufacturing facility experiences, 2) Develop an audit tool to determine, understand, and evaluate the changes that a specific manufacturing facility is experiencing and 3) Develop a measurement scheme for calculations.

1.4 Organization of the Thesis

This thesis consists of five chapters. The first chapter discusses some of the issues currently facing the management in regards to flexibility, provides the overall objective of the thesis and the general layout of the thesis. Chapter two gives a review of previous literature pertaining to FMS. Chapter three provides information on the development of the flexibility audit, the intent of the audit, respondents of the audit and how to interpret the audit. Chapter 4 proposes necessity measures for machine, routing, process, product and volume flexibility. Chapter 4 explains the thought process that went into developing the equations. Finally, chapter 5 contains a summary and the scope for further research in addressing changes and flexibility.

CHAPTER 2

LITERATURE REVIEW

2.1 Background Information

This chapter will be used to introduce some background and previous research that has been completed in Flexible Manufacturing Systems (FMS). In the last couple of years, flexible manufacturing systems has spread through out a variety of industries. Industries such as automobiles, food and consumer products have began to embrace the various philosophies of FMS. Competitiveness, shorter life cycles and cost implications have basically dictated that flexible manufacturing simply become a way of life. Facilities and industries as a whole are realizing that FMS is a necessity for their future survival. The changes that have occurred, ranged from economical reasons to the fluctuating tastes or demands of the customers. Other changes are a direct result of multiple or seasonal products. Consequently, companies existence have become depended upon meeting those multiple and seasonal demands. The ability to adapt or to switch from existing products to new ones, is currently viewed as a strategic and competitive advantage. It is equally important to be able to deliver the new products quickly and efficiently.

A common misnomer is that flexibility automatically equates to automation and automation often signifies high cost. As a result, flexible manufacturing is often considered to be expensive solution. Obviously, this is not always the case and the overall objective is to develop a flexible manufacturing system, while still minimizing cost. In actuality, reduction in costs are possible without requiring large capital investments in

FMS. Facilities can participate in some basic FMS philosophies by minimizing set-up time, minimizing material handling, minimizing inventory levels or maximizing equipment utilization. These basic FMS philosophies can provide a flexible system while reducing costs. Techniques such as line balancing could be utilized to stabilize product flow, reduce cycle times and to reduce or eliminate bottlenecks. This implies that some of the more successful efforts in implementing flexible manufacturing systems required little or no investment in equipment. Other flexible manufacturing systems include a variety of process automation technologies and information systems. When considering automation, it is critical that the process automation technologies and information systems are reflective of the facilities needs. Each FMS should be tailored specifically to address the facility outages. This is needed to ensure that the correct actions are taken to address the facility needs.

The first and most important step is to obtain accurate documentation in regards to the changes that are impacting the facility. A critical aspect of this procedure is to be able to correctly identify the change(s) and to determine the required flexibility that is needed. At this point, it should be noted that all changes do not require corrective actions. Obviously, if no corrective actions are needed, then none should be taken.

This paper will share background information on Flexible Manufacturing Systems (FMS), list five common areas of FMS and discussed an audit that will be utilized. The audit allows individuals to identify changes that are occurring, help prioritize the changes and identify what flexibility is required. In essence, this paper will be an compliment to the paper Das (1994) wrote in regards to identifying a five step flexible solution design process. The first step of his process requires that a facility identifies and quantifies the changes that are impacting a given facility. Step 2 involves the decision of whether a conventional solution can minimize the impact of the change or not. Step three of the process entails correlating the change to one of eight areas of flexibility types, such as machine, routing, product, process operation, volume, expansion, and production. Step four is the design phase of the process. Lastly, step five is the actual implementation of the flexible manufacturing solution (See figure 2.1).

In this paper an audit will be used to capture the changes impacting a facility and the identify the flexibility that is needed.

2.2 Changes

Change is phenomena that is unavoidable in the existing environment. As a result, change is something that all facilities will or has experienced. The phenomena change itself is not new, however, the rate that the change is occurring is unusual in comparison to past history. Consequently, many facilities are currently trying to adjust to the faster rates. The faster rates have resulted in shorter life cycles and shorter learning curves for facilities world wide. Other examples of changes in manufacturing facilities have resulted in changes in product prices, demand or product mixes.

Flexibility in this paper will be described as the ability of a facility to meet the changing needs of their environment, which basically means the ability to redistribute support systems effectively to meet a changing environment. Sethi and Sethi (1990) define flexibility of a system, as its adaptability to a wide range of possible environments that it may encounter. Change will basically be categorize as internal or external. Internal changes will be referred to as an internal stimulus. Internal stimulus are

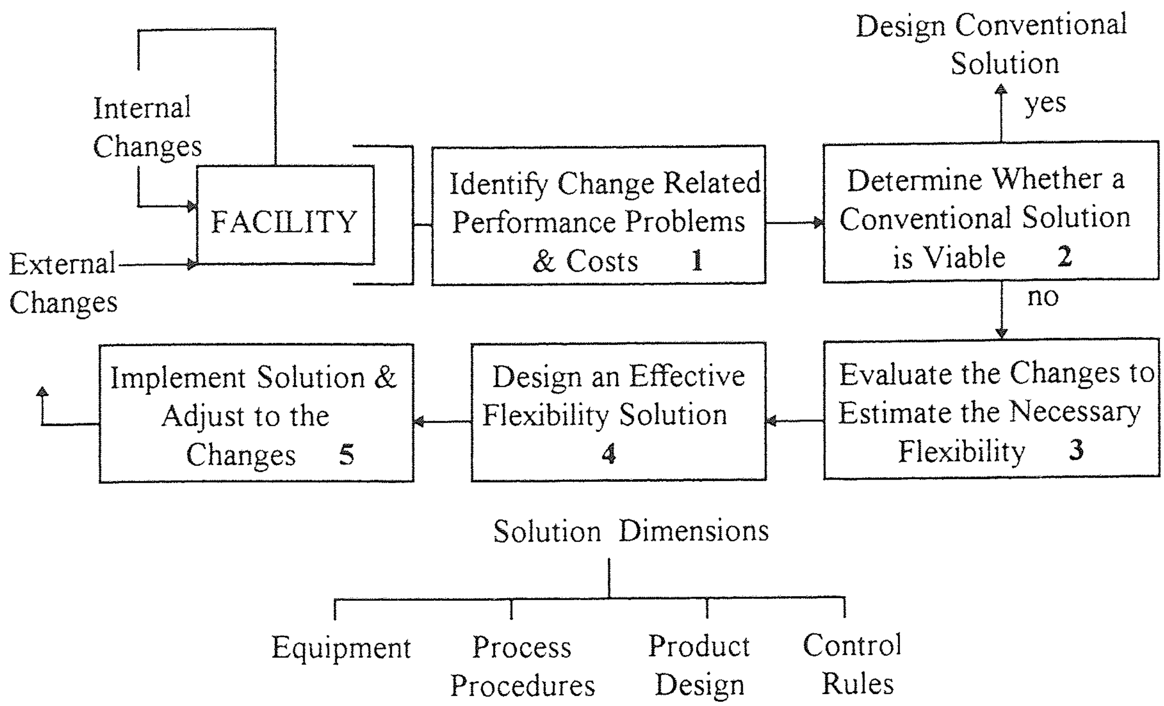

Figure 2.1 The Flexible Manufacturing Solution Design Process

generally driven from within the facility. Internal changes are usually generated by external changes or internal polices. Examples of internal changes are:

- New company policies
- New strategic plans
- Improvement projects

The Procter & Gamble Paper Plant facility (P&G) will be utilized to illustrate an example of an internal change. In this particular case, P&G decided that they needed to increase machine utilization by reducing machine idle downtime. This effort was a directive from the hiearchy, who had a strong desire to increase the overall efficiencies of the tissue lines.

External changes are usually generated by customer needs. Customers can further be defined as consumers or suppliers. It should be noted that facilities have very little control over the external changes that occurred. External changes are usually dictated by environmental issues such as economic issues, competitors and fickle customers. At best, facilities can only try to minimize the impacts of these changes.

Examples of external changes are:

- Supplier demands
- Consumer demands
- Government requirements (OSHA)
- Market stimulus

For example of an external change, P&G will be used again to illustrate this point. This particular example will deal with P&G and one of their suppliers. One of P&G's customers had a need to increase the tissue's large count pack volume. (Large count pack is also known as bundle pack. Bundle packs are large product formats that are usually sold to club stores and supermarkets.) In order to meet several of their club store demands, P&G increased their volume of their large count product to meet customers demand.

Flexibility can further be defined as either short or long term impacts. Short term flexibility will be defined as the effort needed to meet current production needs and/or current business directives. Long term flexibility will be defined as the effort needed to meet future production needs and/or business directives.

As you can see there are many definitions of flexibility and at this time, industry and academia have not come to a clear consensus for the definitions. Flexibility can be used to describe an entire facility or a specify area like machine, process or product flexibility. Brown et al (1984) classifies flexibility into eight areas. However, we will only focus on five of the eight recommended areas of flexibility. Brown et al (1984) and Sethi and Sethi (1990) define five of the flexibility types as:

Machine Flexibility refers to the various types of operations that a machine can perform without requiring prohibitive effort in switching from one operation to another.

Routing Flexibility refers to a manufacturing system's ability to manufacture a product by alternate routes through a system.

Process Flexibility refers to the set of product types that a manufacturing system can produce without major setups.

Product Flexibility refers to the ease with which new products can be added or substituted for existing products.

Volume Flexibility refers to a manufacturing system's ability to be operated economically at different levels of outputs.

Machine, routing, process, product and volume are viewed as the most common flexible types. Each flexibility will be discussed in detail, in addition to some potential measures that could be use to evaluate how well the flexibility needs were met.

2.3 Machine Flexibility

Machine flexibility addresses a machines ability to change to various operations with minimum effort. In this case, minimum effort will refer to cost and time commitments. Machine flexibility is considered to be critical for other flexible systems to exist. Machine flexibility is also considered one of the more important flexibility to have. This is partly due to the fact, that machine flexibility reflects a facilities capability to meet changing customers need and the ability of a facility to offer a variety of products. Machine flexibility allows smaller batch sizes Ranta (1988) and higher machine utilization, which ultimately can lead to inventory savings.

Sethi & Sethi (1990) propose that machine flexibility can be measured by the number of different operations that a machine can perform without requiring more than a specified amount of effort. Other authors place emphasizes on using time and cost as suitable measures.

2.4 Process Flexibility

Process flexibility addresses the capability of a particular equipment/machine to perform more than several or more operations. It is critical that these different production operations can be set up with minimum effort. Minimum effort refers to set up costs and change over times being low to maintain economical benefits.

Process flexibility of a system can be derive from the machine flexibility of machine, operation flexibility of products and the flexibility of the material handling system composing the system Sethi and Sethi (1990).

Propose measures for process flexibility consist of measuring the volume of the set of part types or products that the system can produce without major setups Sethi and Sethi (1990). Falkner (1986) argues that potential measure could be a volume flexxibility, the stability of manufacturing costs over widely varying levels of total production volume. A generalization for volume flexibility could be interpreted as the range of volumes in which a facility can still operate profitably.

2.5 Product Flexibility

Product flexibility is the capability of a manufacturing facility to produce different products with varying mixes or formats. Product flexibility allows a facility to compete in a market where new products are in demand. Another way to view product flexibility is to access the range of varieties a manufacturing system can offer. Production flexibility benefits could result in the ability to reduce time it takes to make a new product.

The obvious measure for product flexibility would be time or cost, it takes to switch from one product to another. Slack (1987) recommends the cost measure should be quantified and expressed in relating to the total production cost.

2.6 Routing Flexibility

Routing flexibility is defined as the ability of a manufacturing system to manufacture a product by various routes through a system. The scheduler generally has the ability to transfer parts and products via different production routes. Schedulers are also utilized to select the best route for manufacturing a product. In essence, schedulers are the experts and can select the most optimum route. Routing flexibility is critical, because it allows the system to select the most optimum route during a production mode. Machine systems with multiple routes are better capable of handling breakdowns or jams in a system, thus resulting in routing flexibility. Overall, routing flexibility allows a system to continue to function, if unanticipated problems should arise. Routing flexibility is a key strategic technique when trying to meet customer delivery times. Routing flexibility can be achieved by having multipurpose machines and machines with overlapping process work areas.

According to Falkner (1986), some planned under utilization of machines (or, redundancy in machines) is needed in order for the system to be able to be reschedule and maintain the overall production rate in case of a machine breakdown.

Various literature has proposed several alternative measures for routing flexibility. One propose measure is to take the average of possible ways in which a product can be processed in a system Chatterjee et al. (1987). A second proposed measure, is the ratio of existing number of links between machines in a system Carter (1986).

2.7 Volume Flexibility

Volume flexibility evaluates a manufacturing system ability to maintain profit at various levels of output. The overall objective is to develop a system that can support fluctuations in volume levels while still maintaining profits. Typically, companies who can make this adjustment are viewed as being profitable and likely to continue to prosper in the future.

In terms of propose measures for volume flexibility, Brown et al. (1984) proposes the measure for volume flexibility should be by how small the volume can be for all part or product types together, with the system still being run profitably. This implies that a facility should be able to produce various volume outputs and still be able to maintain their profit margins.

2.8 Managing Flexibility

Recently, there has been a great deal of focus on how quickly you can get a new product to the market. Sometimes the speed determines whether or not a business will survive or not. Automation is sometimes viewed as a way to get the product on the market quicker and increases flexibility. If a facility should choose automation, the product cost should be at least compatible or better. The quality should also be at least compatible, if not better.

Several potential ways to evaluate automation is through cost, time and quality. This process will involve determining whether the facility was able to reduce cost, get products to the market quicker and whether or not the quality improve.

In order to address shorter life cycles, software such as CAD/CAM have been of great influence. CAD/CAM provided the opportunity to prototype products, which resulted in faster startups and quicker turnovers for products. Ultimately, this results in a range of products being produced more economically at a facility and the opportunity to provide a variety of products at a more rapid rate.

Managing flexibility requires a variety of skills and general management's support. Due to high costs that are usually associated with automation, management is often reluctant of approaching FMS. Adler (1988) believes that management must approach flexibility with renewal energy, if they are to succeed in the future. Adler goes on to state that managerial practices should be reflective of flexibility needs.

FMS studies also emphasizes the importance of organizational and managerial support for manufacturing flexibility. Flexible systems changes the way facilities are currently operating. New managerial philosophies advocate that facilities should manage process improvement overall and not just focus on output solely. It is believed that facilities should focus efforts on projects that develop assets rather than monitoring the costs of daily operations. Thus, forcing facilities to think more long term objectives versus short term objectives.

The organization structure of a FMS environment should be self monitoring. The skills stressed should allow the transfer of knowledge to be obtained from working with one product to another. Thus, allowing continuous improvement and advancement.

According to Jaikumar (1986), the use of small technologically proficient teams to design, run and improve FMS represents a shift in focus from managing people to managing knowledge and from production planning to project selection. Jaikumar believes that this will be the key to future of FMS.

In the past the United States was viewed as not using FMS in the best way. For example, Japanese systems produced on the averaged more than nine times as many part types, and averaged more than twenty times as many new part types introduced per year Kaku (1994). The new challenge for the US is to be able to compete with the Japanese systems and broaden their perspective of their FMS.

Management should realize that it is important to have production people involved as early as possible. This serves two purposes, first is to ensure that the production people understand the direction and the importance of FMS. Secondly, to ensure that the support from the production operation is provided early on.

The group leading the effort for FMS should have full authority to implement and be able to make decisions concerning the design and operation of the FMS. It should also be clear that FMS focus is supported by all levels of management. This type of an environment often results in production employees taking on additional and broader responsibilities. This could result in production employees responsible for a variety pieces of machinery, in addition to the set-up of the various pieces of equipment.

CHAPTER 3

THE DEVELOPMENT OF THE AUDIT

Chapter 3 will be used to share information on the audit that was devised to help facilities capture the changes that are occurring, the reasons why the changes are occurring, and establishes the importance of the changes in respect to one another. The needed flexibility is not an obvious entity and the audit permits us to retrieve the appropriate data.

3.1 Objective of the Audit

The overall objective of the audit was to develop a tool that can used by a company to assess the current flexibility of a manufacturing operations versus where they desire to be. In addition, the audit indicates the flexibility needed to address the change(s) that may be occurring in a facility. (See the end of chapter 3, for a copy of the audit.)

The audit itself is broken into two parts. The first part is a methodology for an organization to identify the change(s) that are occurring in a specific department or facility. This, provides an opportunity for the organization to view the changes that are occurring and to establish a basic understanding why those particular changes are occurring. Companies that possess the knowledge of why change(s) are occurring, will essentially be better equipped to assess the priorities of the changes and in planning to accommodate the change(s). It is critical that all organizations know what changes are occurring and why. This is crucial information if a company wants to be able prioritize their efforts and understand where they need to place their attention.

A critical part of being able to prioritize, requires that an organization understands the effort level required to efficiently accommodate the changes and the frequency at which the changes will occur. The performance impact provides a perspective on how the change is going to impact the overall system. If a change requires a great deal of effort to address it, the planning and organizing of the strategies becomes even more critical. It is equally important for a company to understand the effort level, so that the correct resources are assigned. Frequency is needed in determining the appropriate support level for the changes in an organization. Frequency can often result in the reason for a specific change to be given a higher priority than another.

The second part of the audit addresses the flexibility needed to meet the change. There are five basic flexible systems that will be used to address the changes. The flexibility that will be used are machine, routing, process, product and volume flexible systems, which were previously discussed in Chapter 2. Once the needed flexibility is selected, a list of questions under the specific flexibility are asked. The questions help determine the current capability and the needed capability. If the desired capability is greater than the current actual outcome, adjustments are required. The second part of the audit helps individuals list changes, determine possible solutions for the changes and evaluate the feasibility of those solutions. Measures should be established to determine whether the solutions selected will meet acceptable performance level(s) or not. After the audit is completed, an organization will have the ability to:

- Clearly define the changes that are occurring in their business.
- Understand why the changes are occurring in their business.
- Be able to rank the changes from most important to least.

- Establish the flexibility needed.
- Identify solutions to achieve the needed flexibility.
- Identify measures to evaluate solutions effectiveness.

3.2 Audit Flow

The flow of the audit is designed so as to identify all the changes that are currently occurring in the business. Once that has been established, participants should have a basic understanding of why those changes are occurring. In addition to understanding why the changes are occurring, participants are expected to have some knowledge about the effort expended by the company in responding to the changes. Furthermore, the designers will estimate the frequencies at which these changes will be occurring. The effort level and frequencies will be used to establish the rank of the individual changes. The actual changes ranking will depend upon the importance of the changes. This will follow the pattern of the most important to the least important. The next step involves identifying the specific flexibility needed. The most crucial step is developing solutions that would achieve the needed flexibility economically. The measures determine, should be able to evaluate the overall effectiveness of each proposed solution prior to implementation.

3.3 Respondents of the Audit

Who should use the audit ? Basically, individuals who understand the manufacturing environment of the company and can answer the questions accurately and completely. The participants of the audit at a minimum should include individuals who are familiar with the equipment involved, process systems, maintenance systems and current business direction. The knowledge of the equipment will allow the group to know what is feasible or not in regards to the equipment. The understanding of process and maintenance systems help identify the needed flexibility needed to address the changes. The understanding of why changes are occurring and the current business direction are critical when establishing priority of the changes.

There are several recommendations on the approach of filling out the audit. The first recommendation is to let various individuals with various background fill out the audit individually. The proctor / consultant responsibility will include collecting the audit and interpreting the feedback from the individual participants.

The second recommendation is to complete one audit as a collective group. This recommendation is more thorough then the first recommendation, because it allows for group discussion.

The third recommendation and probably the best option, is a combination of recommendation one and recommendation two. First individuals would fill out the audit individually. The second part would consist of sharing the information with the larger group to help develop one audit for the entire group. By allowing the individuals to fill out the audit individually, you will increase the chances of receiving unbiased feedback from everyone. The group discussion provides an opportunity to double check the participants responses and provides the opportunity to clear up any misinterpretations.

It should be noted that each organization is different and have unique needs. Overall, participants should have a fairly good understanding of the core business. Core business will be defined as the "work" that makes the business profitable. Example: the actual product of tissue lines.

After the audit is completed, a summary sheet should be fill out. The summary sheet is a one page sheet that lists the changes, the reasons, effort levels, frequencies and performance impact. It also provides space for the solutions and the acceptable rating that were pre-determined. This sheet should be used to inform the organization of the results from the audit. (See figure 3.1)

The number of participants depends on the size on the organization. A small size company would probably need anywhere from three to five people, a mid size company would need approximately five to eight people, a large company could potentially need a minimum of eight people. The number of participants truly depends on how an organization is set up and how many responsibilities each individual may hold. It could be possible for one individual to have one job that holds multiple responsibilities, therefore, resulting in an individual who may possess knowledge in several areas. Overall, the number should be reflective of what is needed to accurately answer the questions.

3.4 Interpretation of the Audit

Listing the changes that occur in a business allows an organization to quickly evaluate all the activities that are simultaneously occurring. Stating the reason why the changes are occurring, starts the foundation of establishing the importance. The effort level and frequency rating will provide data to establish the rankings of the changes. The format is to place the changes in order from the most important to the least important. The figure change that has the highest score will be rank the most important and so on. By establishing the rank, the organizations can easily decide which changes they should focus on first. Thus, prioritizing the changes for the organization to address. Part two of the audit allows participants to place the change in the flexibility area that is reflective of the

Final Summary Report Date: ___________ Number of Respondents: ___________						
Change	Reasons	Effort Level L M H	Frequency L M H	Performance Impact L M H	Solutions	Ratings

Figure 3.1 Final Summary Report

change. This step allows the designers to analyze what flexible system a change appropriate fits in. Once the flexibility is determined, the participants go to the appropriate category and fill out the appropriate questions. The questions help establish what the current capability versus the needed capability. If the current is less than the needed, the questions allows the participants to think of viable, economical solutions. Once the solutions have been selected, the appropriate measures need to be assigned. After the measures are established, the organization will later decide if the solutions selected are meeting the goals that were previously established. If the solutions do not met the desired goals, then participants must generate new solutions to evaluate.

3.5 Review of Audit Tests

Several dry runs of the audit were completed in a leading United States consumer manufacturing facility. Individuals involved in participating in the audit consisted of a process engineer, maintenance technician, team leader, process engineer and department manager. These individuals provided feedback on the flow of the audit, usefulness and the relevancy of the questions. Initial thoughts of the flow were positive. All the participants felt the flow of the audit followed a logical step by step procedure. Participants recognized the need or the importance of being able to document all the changes and the reasons why. Participants felt that it was clearly necessary to have the changes and the reasons clearly documented. The reasons, effort level and frequency helped the participants establish the importance of the changes relative to one another. As a result of confusion in how to rank the changes, an additional measure was added to the effort level and frequency. This new measure was called the performance impact. By multiplying the effort level times the frequency and the performance impact, participants were clearly able to establish the ranking. Thus, resulting in the participants being able to prioritize.

Initially there was some confusion in how part one tied within part two. Participants struggle with correlating the changes occurring in the environment with the flexibility needed. Some of the confusion was a result of not being familiar with the vocabulary or not being clear of the intent of the audit. Participants recommended that a completed audit should be shared with the participants, so that the participants would have something to compare their answers to. It was also felt that a thorough overview explanation of the audit was needed prior to starting the audit. As a result of that feedback, a flow chart was created. (See figure 3.2)

In addition, some feedback was given on the actual wording of the audit. Participants found certain sections too wordy. The feedback acquired helped clear up some of the wording on the audit.

3.6 The Audit

The audit itself has six main questions or sections (See the end of chapter 3). Several of the questions are broken into subsections. For example, part 2 of the audit consists of two major questions and each question has five subsection which are labeled from A-E. This section of the paper will be used to describe and explain each question of the audit.

Part 1 of the Audit:

<u>Question 1- List the changes that are currently occurring in your business.</u>

The intent of this question is to ensure that the individual or the group, lists all the changes that are currently occurring in their department or organization as a whole.

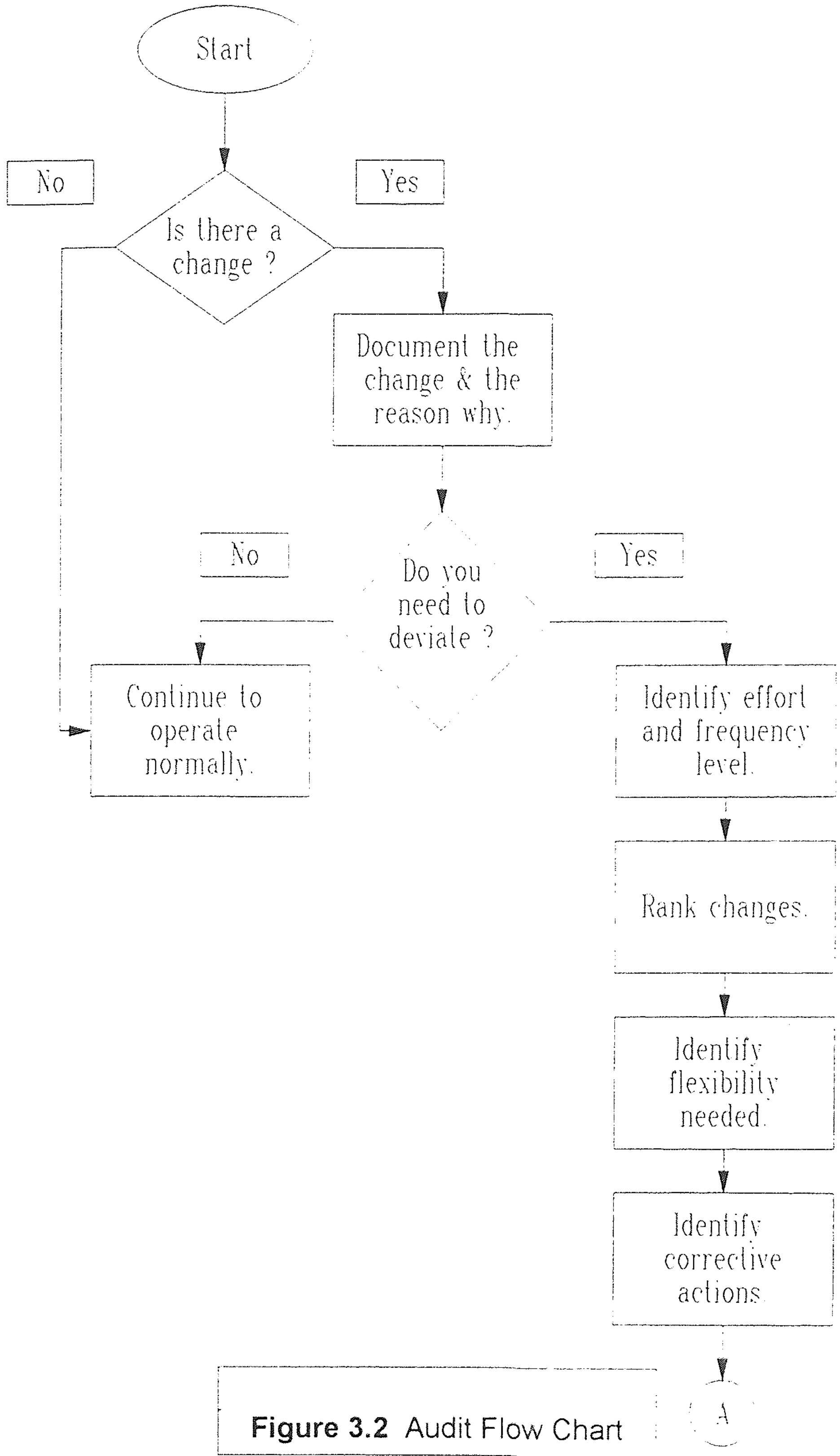

Figure 3.2 Audit Flow Chart

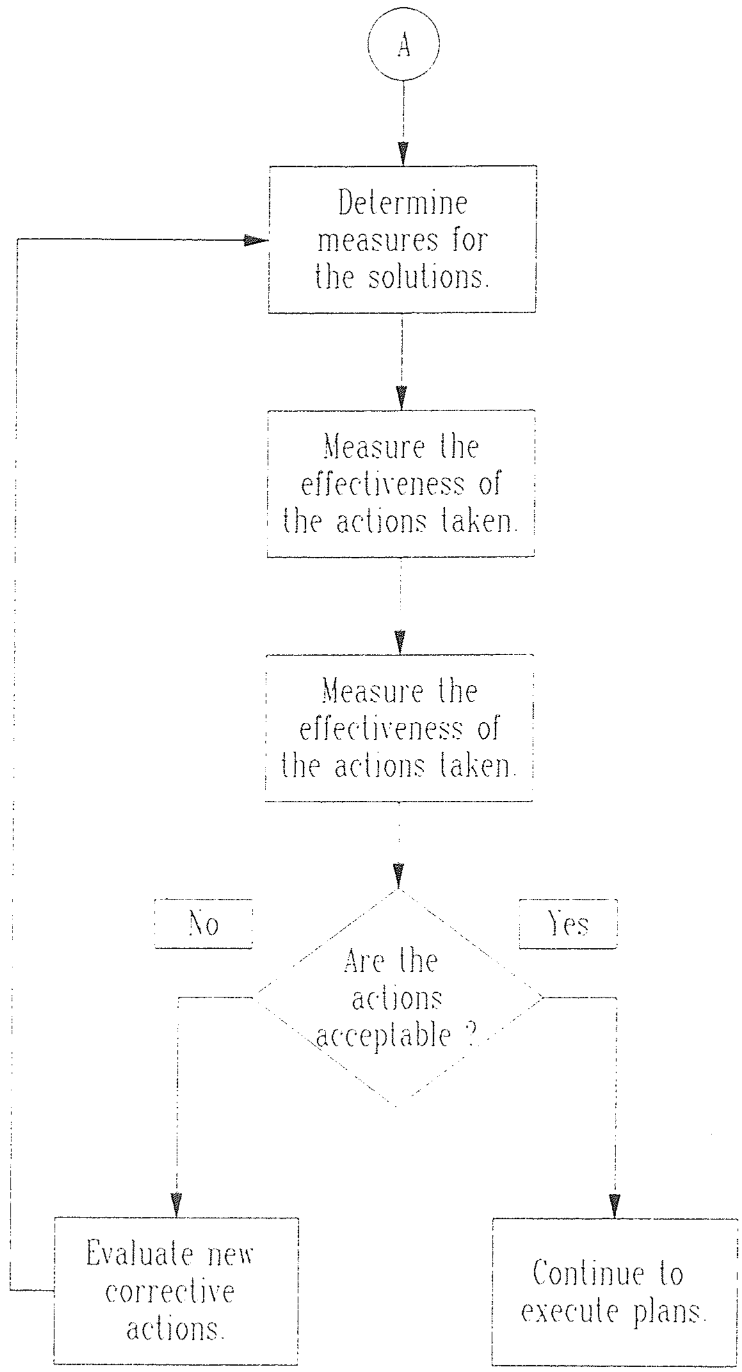

Figure 3.2 Audit Flow Chart

This also provides the participants an opportunity to receive a quick overview of all the changes that are simultaneously impacting their business.

Question 2 - List the reasons why the individual changes are occurring.

The intent of this question is to provide the opportunity for participants to understand why the changes are occurring. This information will later be used by the participants in determining the priority of the changes.

Question 3 - Determine the effort level, frequency and the performance impact.

(0 represents that the change requires minimum effort to support, 5 indicates maximum effort. 0 under frequency represents that the change does not occur often, 5 indicates the frequency is often. 0 under performance impact indicates that the change will have minimum impact on the overall performance, 5 indicates that the change will have maximum impact on the overall performance.)

This question helps participants quantify the impacts of the changes, in regards to the effort level, frequency and the performance impact of the changes. The scale is a graphic tool used to weigh the impact of the changes. The total value is obtained by multiplying the effort level rating x frequency rating x performance impact. The change with the highest number will be rank first and so on. Note: The total value and the performance impact was added to help participants be able to prioritize and distinguish between what changes have a higher priority.

Question 4 - Rank changes from the most important to the least important utilize the letter associated with the change.

The intent of this section is to prioritize the changes. An organization may not have the time or resources to work on all the changes simultaneous. So, this provides an opportunity for an organization to rank the changes and determine what are priorities based on the reasons, effort level, frequency and performance impact.

Part 2 of the Audit

Question 5 - Identify what type of flexibility is needed to address the change.

(Fill in the changes identified next to the appropriate flexibility.)

This question helps the participants select the flexibility that is needed to address the changes that are occurring. Once the flexibility is selected, the participants goes to the appropriate area.

Section 6 - Go to the appropriate category and complete the appropriate questions.

In this section there are 5 categories to chose from machine, routing, product, process and volume flexibility.

Machine Flexibility:

a. What is the number of operations the machine was designed for ?

This question helps determine what is the existing number of operations the machine was designed for. This addresses the original specs of a machine or what the designer had in mind for the number of operations. This information is often provided in the specs.

b. What is the number of operations the machine can actually perform ?

This questions provides the reality data or the actual number of operations a machine can do. It is not uncommon for an equipment to be designed for a certain number of operations, but actually perform less then that. This tends to be more common with prototype equipment.

c . Identify the reason for the delta, if the number of design operations is greater than the number of current operations.

If the actual number of operations is less then the designed operations, then there is an opportunity for improvement. This questions forces the participants to analyze, why the equipment is not performing as it should. If vice versa and the current number of operations exceeds designed spec, then stop at that point, unless the participants have retrofitted the equipment and consequently have a new design spec for the number of operations.

d. Identify appropriate action steps to address the changes.

This question forces the participants to establish solutions that could address the delta. This begins the first phase of problem solving.

e. What measure could be used to evaluate the action steps selected ?

The intent of this question is to establish viable measures for the solutions generated in section d.

f. What is considered to be an acceptable rating ?

The intent of the questions is to allow participants to establish acceptable ratings for the solutions that were selected in section d. The acceptable ratings are basically pre-determined goals set by the participants. Thus, given the participants a goal to strive for.

g. Evaluate action steps (Acceptable or Not Acceptable).

After the implementation of the solutions, participants should revisit and analyze whether the solutions performance met the participants preset goals.

<u>Routing Flexibility</u>

a. What is the average number of ways in which a product can be processed ?

This question helps determine what is the current number of ways a product can be processed.

b. Is the current capability sufficient ? yes or no.

The intent of this question is to determine if current capability is adequate. If the answer is yes, then nothing should be done, unless participants are seeking additional ways to process products. If the response is no, then participants should continue to part c.

c. If no, brainstorm other ways the products can be processed.

The intent of the questions is to develop viable solutions to increase the number of ways the products can be processed.

d. Select the best options.

This section requires that participants select the solution that is the most feasible, economical and will be most probable to yield the desired results.

e. What measures could be used to evaluate the action steps selected ?

The intent of this questions is to establish measures for the solutions generated in section d.

f. What is considered to be an acceptable rating?

Allows participants to establish acceptable ratings for the solutions that were selected in part d under routing flexibility.

g. Evaluate action steps (Acceptable or Not Acceptable).

The intent of this question is basically to analyze whether the solutions performance met the participants preset goals.

<u>Process Flexibility</u>

a. What is the number of products that the system was designed to produce, with minimum impact ?

This question helps determine what is the number of the products a system was designed to produce with minimum problems.

b. What is the number of products that the system is capable of producing with minimum impact ?

This question helps determine the current number of products a system can produce, regardless of the original design spec.

c. Identify the reason for the delta, if the number of products the system can produce is greater than the system is currently producing.

If the actual number of products is less then the designed, then there is an opportunity for improvement. If vice versa, the actual number of products is greater that the designed, stop at that point, unless a the organization has developed new target values for the number of products.

d. Identify appropriate action steps to address the changes.

This section begins the first phase of problem solving.

e. What measure could be used to evaluate the action steps selected ?

This question allows participants to establish solutions that could potentially eliminate the delta.

f. What is considered to be an acceptable rating ?

The intent of this question, is to establish viable measures for the solutions generated.

g. Evaluate action steps (Acceptable or Not Acceptable).

The intent of this question is to analyze whether the solutions performance met participants pre-determined goals.

Product Flexibility

a. Evaluate material handling, machine and operation flexibility.

This forces the participants to determine the existing flexibility of material handling, machine and operation.

b. Identify ways to improve one or more of the above listed flexible systems.

The participants may chose to focus on one of the flexible system or several of them simultaneous. The objective is to determine what is necessary to meet the existing demands.

c. What measure could be used to evaluate the action steps selected ?

The intent of this question, is to establish viable measures for the solutions generated in this section.

d. What is considered to be an acceptable rating ?

The intent of the questions is to force participants to establish acceptable ratings for the solutions that they selected in part b in product flexibility. The acceptable rating are pre-determine goals set by the participants.

e. Evaluate action steps (Acceptable or Not Acceptable).

The intent of this question is to analyze whether the solutions selected performed at acceptable levels or not.

Volume Flexibility

a. What is the desired volume flexibility ?

This question allows the participants to determine what their existing volume flexibility capability.

b. What is the current volume flexibility ?

This question clarifies what the volume flexibility demand actually is.

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The following pages after the cover sheet, consist of the actual sheets of the audit that was developed for this paper.

Cover Sheet

Name: ______________________________ **Date:** ______________________

Organization: ________________________ **Title:** ______________________

Department: __________________________

Individual _________ **Group** _________ **(check the appropriate area.)**

Number of the people in the organization: _______________

State the process used: _______________________________

State the number of products produce: __________________

List the products:

____________	____________	____________
____________	____________	____________
____________	____________	____________
____________	____________	____________
____________	____________	____________
____________	____________	____________

Audit
(Part 1)

1. List the changes that are currently occurring in your business.
   (i.e. increased volume, different products, or various product mixes)

a.______________________ e.______________________

b.______________________ f.______________________

c.______________________ g.______________________

d.______________________ h.______________________

2. List the reasons why the individual changes are occurring.
   (i.e. company policies, Government regulations or market stimulus)

a. ____

b. ____

c. ____

d. ____

e. ____

f. ____

g. ____

h. ____

3. Determine the effort level, frequency and the performance impact of the changes: (0 represents that the change requires minimum effort to support, 5 would indicate maximum effort. 0 in regards to frequency represents that the change does not occur very often, 5 indicates the frequency is often. 0 under performance impact represents that the impact is minimum, 5 indicates that the impact is great.)

Add the values from effort level and frequency to determine the total score.

	Effort Level Rating		Frequency Rating		Performance Impact
a.	0 1 2 3 4 5	X	0 1 2 3 4 5	X	0 1 2 3 4 5

Total __________

	Effort Level Rating		Frequency Rating		Performance Impact
b.	0 1 2 3 4 5	X	0 1 2 3 4 5	X	0 1 2 3 4 5

Total __________

	Effort Level Rating		Frequency Rating		Performance Impact
c.	0 1 2 3 4 5	X	0 1 2 3 4 5	X	0 1 2 3 4 5

Total __________

Effort Level Rating **Frequency Rating** **Performance Impact**

d. 0 1 2 3 4 5 X 0 1 2 3 4 5 X 0 1 2 3 4 5

Total ___________

e. 0 1 2 3 4 5 X 0 1 2 3 4 5 X 0 1 2 3 4 5

Total ___________

f. 0 1 2 3 4 5 X 0 1 2 3 4 5 X 0 1 2 3 4 5

Total ___________

g. 0 1 2 3 4 5 X 0 1 2 3 4 5 X 0 1 2 3 4 5

Total ___________

Effort Level Rating		Frequency Rating		Performance Impact
h. 0 1 2 3 4 5	X	0 1 2 3 4 5	X	0 1 2 3 4 5

Total ___________

4. Rank changes from the most important to the least important utilizing the letter associated with the change.

   (This is determined by selecting highest total number to the lowest total number.)

1.________ 2.________ 3.________ 4.__________

5.________ 6.________ 7.________ 8.__________

AUDIT
(Part 2)

Classify the changes in the appropriate category:

5. Identify what type of flexibility is needed to address the change:
(Fill in the "change" identified next to the appropriate flexibility.)

________________________ a) Machine Flexibility - refers to the various types of operations that the machine can perform with out requiring massive efforts when switching from one operation to another.

________________________ b) Routing Flexibility - refers to a manufacturing systems ability to manufacture a product by alternate routes through the system.

________________________ c) Process Flexibility - refers to a manufacturing system which refers to different set of product types that the system can produce with out major set-ups.

________________________ d) Product Flexibility - refers to the ease with which new product can be added or substituted for existing products.

________________________ e) Volume Flexibility - refers to a manufacturing system to operate economically at different levels.

6. Go to the appropriate category and complete the appropriate questions:

A. Machine Flexibility ____

a. What is the number of operations the machine was designed for ? __________.

b. What is the number of operations the machine can actually perform ? _________.

c. Identify the reason for the delta, if the number of design operations is greater than the number of current operations.

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d. Identify appropriate action steps to address the change(s).

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e. What measure could be used to evaluate the action steps selected ?

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f. What is considered to be an acceptable rating ?

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g. Evaluate action steps (Acceptable or Not Acceptable).

B. Routing Flexibility ______________________

a. What is the average number of ways in which a product can be processed ____________.

b. Is the current capability sufficient ? yes or no.

c. If no, brainstorm other ways the product(s) can be processed.

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d. Select the best option(s).

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e. What measure could be used to evaluate the action steps selected ?

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f. What is considered to be an acceptable rating ?

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g. Evaluate action steps (Acceptable or Not Acceptable).

C. Process Flexibility ____________________

a. What is the number of products that the system was designed to produce, with minimum impact ?____________.

b. What is the number of products that the system is capable of producing with minimum impact ? ____________.

c. Identify the reason for the delta, if the number of products the system can produce is greater than the system is currently producing.

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d. Identify appropriate action steps to address the change(s).

e. What measure could be used to evaluate the action steps selected ?

f. What is considered to be an acceptable rating ?

g. Evaluate action steps (Acceptable or Not Acceptable).

D. Product Flexibility ____________________________________
a. Evaluate material handling, machine and operation flexibility.

b. Identify ways to improve one or more of the above listed flexibilities.

c. What measure could be used to evaluate the action steps selected ?

d. What is considered to be an acceptable rating ?

e. Evaluate action steps (Acceptable or Not Acceptable).

E. Volume Flexibility ____________________

a. What is the desired volume flexibility ?__________.

b. What is the current volume flexibility ?__________ .

c. Identify ways to improve the volume flexibility, if the desired volume flexibility is greater the current volume flexibility.

d. List ways to build in volume flexibility economically.

e. What measure could be used to evaluate the action steps selected ?

f. What is considered to be an acceptable rating ?

g. Evaluate action steps (Acceptable or Not Acceptable).

Note: Examples of measuring results:

% improved
% increased
downtime reduce
changeover time reduce
response to change
cost savings

If your choices do not meet your goal(s), re-evaluate choices.

CHAPTER 4

PROPOSED NECESSITY MEASURES FOR FLEXIBLE SYSTEMS

The necessity measures were developed to help facilities establish the necessity measures needed to achieve their desired flexibility. Thus, providing facilities with a goal to aim for.

4.1 The Classification Scheme for Manufacturing Flexibility.

Das (1994) developed a classification scheme for manufacturing flexibility. The scheme shows that certain flexible systems need to come first for other flexible systems to exist. For example, product flexibility needs to come prior to process flexibility and process flexibility should become before machine flexibility. (See figure 4.1 for complete classification scheme.) As a result of this scheme, the necessity measures will follow the same pattern as product, process machine, routing and volume flexibility.

It should also be noted that all of the necessity measures for flexible systems should be modified and massaged to adapt to the specific facility. The intent was to developed basic equations and basic parameters that should be considered in determining necessity measures. The parameters listed in the equations are not necessary all the parameters that should be considered. The parameters used should actually depend on the facility and their needs. Equally, it is not necessary to use all the parameters that were listed, but the parameters should be evaluated at least. The assumption was also made that the marketing analysis was completed and shared with the manufacturing facilities.

Thus, the manufacturing facility should have an idea of what is expected of them from the customers and the company.

4.2 The Necessity Measures for Product Flexibility

The definition for product flexibility in this paper refers to the ease with which new products can be added or substituted for existing products. In this section, a propose equation for the necessity measure for product reliability will be shared. Product flexibility is important to a facility, if the facility is increasing the number of new products they are introducing within a certain time. There are several factors that should be considered when trying to determine the necessity measure for product flexibility. Areas that should be considered are:

- The average cost it takes to introduce a new product.
- The cost a facility is willing to spend on the introduction of a new product.
- The time a facility is willing to spend on the setup for the introduction of new product.
- Market information that determines what is a good number to offer in product variety.
- The time between new products.
- The number of products introduced per interval.

The introductions of new products are needed to help facilities compete with competitors and the fact that products often become obsolete. FMS allows a facility to be able to produce a variety of products at economical costs. New products introduced to a facility often results in costs associated with setup, training, new raw materials, etc. Management generally has an ideal how much they are willing to invest in new products and how much they expect to gain as a result of their investment. Benefits could be established as profits, growth in sales or expanding market shares. The ideal situation is to introduce new products with zero costs associated with the introduction of new products. However, it is highly unlikely that new products can be introduced with zero costs, therefore the realistic objective is to introduce new products with minimum cost.

The necessity measure for product flexibility helps a facility determine what is the necessary flexibility needed to meet customer demands. The thought process around the equation was to develope an equation that took in account cost and setup time when dealing with new products. The $R_{cost} + R_s = 1$ is a way to tie the relative importance of cost versus time. The actual equation is as follow:

$$Pflex_{nec} = R_{cost} (\beta_{intro} \times N_{intro}) / E_{intro} + R_s (\beta_s \times I_{intro}) / T_{intro}$$

where,

β_{intro} = Maximum percentage a facility is willing to spend on the introduction of a new product.

β_s = Maximum tolerated percentage of time a facility is willing to spend on the setup of the introductions of the new product(s).

I_{intro} = The interval between the introductions of new products.

N_{intro} = The number of products introduced per interval.

T_{intro} = The time to set-up a facility for the introduction of new products.

R_{cost} and R_s = The importance of set-up cost and time in respect to one another.

In this particular case, $R_{cost} + R_s = 1$.

E_{intro} = The average cost (expenses) to introduce the new product(s).

It should be noted that E_{intro} should include items such as new raw material costs + cost associated with the setup time for new products (downtime) + cost associated with startup or a learning curve for new products (lost of efficiencies) + cost associated with the new equipment (including retrofitted equipment) + cost associated with training (new process and equipment, etc.). In this case, the assumption that market analysis was completed and the facility is already given the number of product types should be offered.

4.3 The Necessity Measure for Process Flexibility

As stated in chapter 2, process flexibility refers to the set of product types a manufacturing system can produce without major set-ups. Some basic factors that should be evaluated when determining the necessity measure for process reliability are:

- The number of product types a given system can handle with minimum problems.
- The number of operations a given system can perform.
- Efficiency of the individual operations.
- Estimate / forecast of how many product types a facility will have to perform based on demand.
- Market influence (stimulation).

The estimate for the number of product types based on customers is a very critical parameter to consider. It is also, the most difficult to predict and subject to a great deal of fluctuation. The idea is to get an estimate of how many product types is needed to offer the consumer a variety and to kept their interest. In developing the basis for a necessity measure, three areas were considered:

- The number of product types a specific equipment can perform.
- The number of operations a specific equipment can do.
- Efficiency of the operations perform on a specific equipment.

This yielded a basic formula of:

$$Prflex_{nec} = S_1(Q_2 - Q_1) + S_2(L \times \alpha)$$

where,

Q_2 = The needed number of product types.

Q_1 = The current number of product types.

L = number of operations a specific equipment can do.

α = efficiency of the operations perform on a specific equipment.

S_1 and S_2 were used to show the relationship and importance of the relationship the number of product types in respect to the number of operations. In this particular case, $S_1 + S_2 = 1$. This equation is broken into two specific areas, the needed number of product types plus the number of operations needed with their efficiency. The assumption is that the market demand has been estimated and the facility has been charged with delivering the directions.

4.4 The Necessity Measure for Machine Flexibility

Machine flexibility refers to the various types of operations that a machine can perform without requiring prohibitive effort in switching from one operation to another. Machine flexibility is important because it helps reduce machine idle time. The more operations a

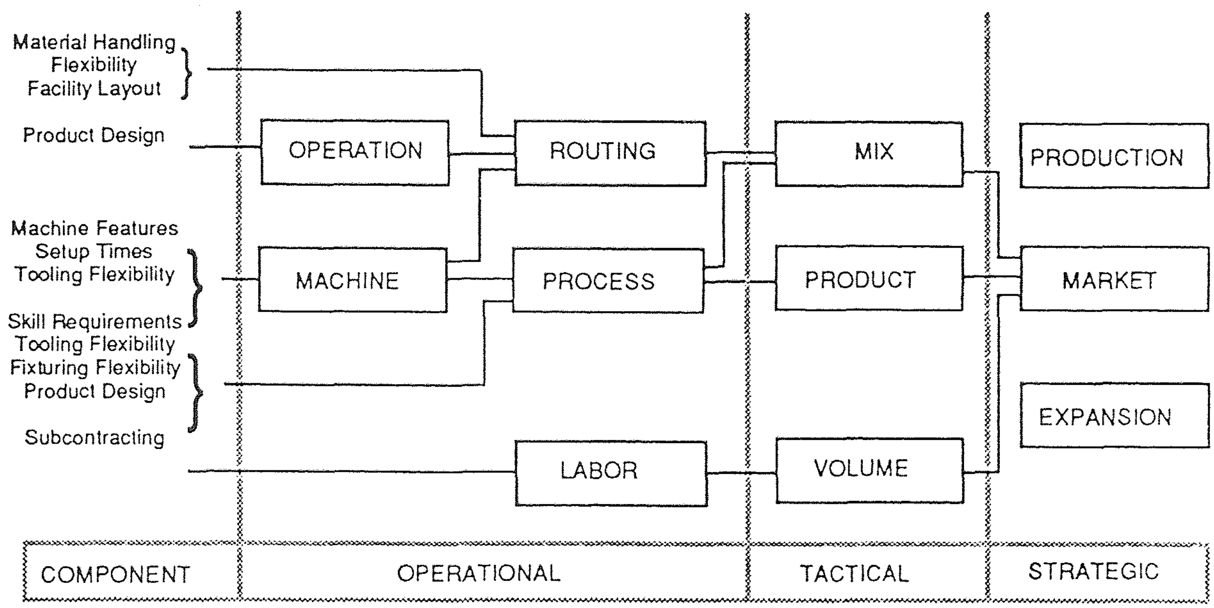

Figure 4.1 A Proposed Classification Scheme for Manufacturing Flexibilities

machine can perform, the less likelihood of the machine being idle for large portion of the time. The logic in defining the basic equation for the necessity measures dealt with developing several parameters that were thought to be critical for machine flexibility. These parameters were identified as follows:

- The efficiency of the machine.
- Pertinent operations the machine can perform.
- Reliability of the equipment.

Using the above parameters resulted in the following equations.

$$Mflex_{nec} = (O_2 - O_1) + K$$

O_2 = The target number of operations.

O_1 = The current number of operations.

K = The number of operations the machine needs to perform to maintain economical status.

4.5 The Necessity Measure for Routing Flexibility

Routing flexibility refers to a manufacturing system's ability to manufacture a product by alternate routes through out the system. The routing flexibility is very important because it allows for various outlets to process a product through a system. This could be very useful, when a facility is experiencing problems, jams, downtime with one or more of the routes. One should also realize that multiple routes or outlets do not ensure that the efficiency of the process will be equivalent. Usually, each route has its own efficiency and independent processing time. This means that the production may not come to a complete stop, but it might be performing at usual or desired level. Areas that should be considered when addressing routing flexibility are:

- The number of alternate routes.
- The efficiency of the routes.

- The processing times of each routes.

The thought process for this necessity measure was to focus on the basic efficiency of the individual routes while also focusing simultaneous on the processing times of the routes. Thus, resulting in the following formula:

$$Rflex_{nec} = \Sigma(M / N) \times \Sigma(P/100)$$

M = The efficiencies of the routes.

N = The total number of routes available for use.

P = The average processing time for a route.

4.6 The Necessity Measure for Volume Flexibility

The term volume flexibility refers to a manufacturing system's ability to operate economically at different levels of output. Some factors that should be considered when developing the necessity measure for volume flexibility.

- Volume target rate.
- Current Volume rate.
- Volume level where the facility would break-even.
- Allowable inventory on hand at the facility.
- Market trends (history).
- Inventory on hand (percentage).

The necessity measure for volume flexibility is a critical measure and area. As a result of today's fluctuating market, it has become increasingly important and difficult for a facility to be capable of functioning at different levels of output while still maintaining profit margins. The basic formula would consist of:

$$VFlex_{nec} = (V_2 - V_1) + L$$

V_2 = Volume target rate

V_1 = The current volume rate

L = The volume at which the facility would break-even.

The assumption is made that market analysis has been completed, and should be viewed as a given.

CHAPTER 5

SUMMARY

5.1 Summary

FMS is clearly the way to the future. FMS can be clearly utilized to effectively influence operating parameters, such as lead-times, throughput, machine utilization, quality, inventory and other important measures. Future successes of FMS technology will clearly depend upon cost, reliability, ease of use, the ability to respond to changes in product mixes.

Facilities should look to maximize flexibility the most cost effective way they can. This could pertain to FMS philosophies touch as better product designs, better planning and control , line balancing, or pursuing long term commitments with customers and suppliers. All which would help and contribute to minimizing the impact of change and uncertainty, and create an environment where facilities can become more capable of responding to change. Gerwin (1993) suggests that we become proactive when addressing the fluctuation of the market. He advocates instead of playing catch up, set the trend by offering a variety of products, being flexible and responsive to customers needs. Those facilities who can achieve it will be setting the standard for others to try to obtain.

It is obviously important for facilities to have a sound understanding about what things that are impacting their facility or organization. In addition, to understanding the lead to ultimately being able to better prioritize and allow facilities to determine the correct resources to execute the job effectively. The audit in chapter 3, provided one perspective on how to achieve this.

APPENDIX

Audit
(Part 1)

1. List the changes that are currently occurring in your business.
   (i.e. increased volume, different products, or various product mixes)

a. *30 roll / 350 sheet count*

b. *Winder speed up*

c. *54 roll bundle pack*

d. *Short cores*

2. List the reasons why the individual changes are occurring.
   (i.e. company policies, Government regulations or market stimulus)

a. *(30 roll / 350 sheet count) - compete for Clubstores business.*

b. *(Speed probes) - increase volume out-put.*

c. *(54 roll bundle pack) - compete with competitors large count pack.*

d. *(Short cores) - used for test market for new products and reduce costs.*

Effort Level Rating | **Frequency Rating**

d.

Effort Level Rating: 0 1 2 **3** 4 5

Frequency Rating: 0 **1** 2 3 4 5

Total **4**

4. Rank changes from the most important to the least important utilizing the letter associated with the change.

   (This is determined by selecting highest total number to the lowest total number.)

   1. **a** 2. **c** 3. **e** 4. **d**

AUDIT
(Part 2)

Classify the changes in the appropriate category:

5. Identify what type of flexibility is needed to address the change:
(Fill in the "change" identified next to the appropriate flexibility.)

30 roll / 350 sheet count a) Machine Flexibility - refers to the various types of operations that the machine can perform with out requiring massive efforts when switching from one operation to another.

__________________ b) Routing Flexibility - refers to a manufacturing systems ability to manufacture a product by alternate routes through the system.

54 roll bundle pack c) Process Flexibility - refers to a manufacturing system which refers to different set of product types that the system can produce with out major set-ups.

Short Cores for Tissue lines d) Product Flexibility - refers to the ease with which new product can be added or substituted for existing products.

Speed Probes e) Volume Flexibility - refers to a manufacturing system to operate economically at different levels.

6. Go to the appropriate category and complete the appropriate questions:

A. Machine Flexibility *30 roll / 350 sheet count*

a. What is the number of operations the machine was designed for ?
3

b. What is the number of operations the machine can actually perform ?
3

c. Identify the reason for the delta, if the number of design operations is greater than the number of current operations.

d. Identify appropriate action steps to address the change(s).

1. *Change the count gears, modify the Winder to accept different thickness of paper.*
2. *Change the height of the logsaw when cutting logs*.

e. What measure could be used to evaluate the action steps selected ?

1. *Length of time it takes to complete a changeover*.

f. What is considered to be an acceptable rating ?

Efficiency of the line (including the changeover time) should be 75 % for that particular day.

g. Evaluate action steps (Acceptable or Not Acceptable).

B. Routing Flexibility ______________________________

a. What is the average number of ways in which a product can be processed __________.

b. Is the current capability sufficient ? yes or no.

c. If no, brainstorm other ways the product(s) can be processed.

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d. Select the best option.

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e. What measure could be used to evaluate the action steps selected ?

f. What is considered to be an acceptable rating ?

g. Evaluate action steps (Acceptable or Not Acceptable).

C. Process Flexibility *54 roll bundle pack*

a. What is the number of products that the system was designed to produce, with minimum impact ? 6 .

b. What is the number of products that the system is capable of producing with minimum impact ? 4 .

c. Identify the reason for the delta, if the number of products the system can produce is greater than the system is currently producing.
The bagger currently can handle bundles greater than 48 rolls in a stack.

d. Identify appropriate action steps to address the change(s).

Modify the bagger to accommodate 30 rolls. Includes: flights, timing elevator and bags fitting the new size bundle.

e. What measure could be used to evaluate the action steps selected ?

Evaluate the changeover time for the bagger.

f. What is considered to be an acceptable rating ?

Changeover should not require more than 1.5 hours.

g. Evaluate action steps (Acceptable or Not Acceptable).

D. Product Flexibility Short Cores 45 inches"

a. Evaluate material handling, machine and operation flexibility.

Core bins, coremachines

b. Identify ways to improve one or more of the above listed flexible systems.

Shorten the mandrel on the coremachine, use a faster drying glue.

c. What measure could be used to evaluate the action steps selected ?

Defects per million, whether the equipment hold the designated length.

d. What is considered to be an acceptable rating ?

10 defects per million, 955 of the cores are with in specifications.

e. Evaluate action steps (Acceptable or Not Acceptable).

E. Volume Flexibility *Speed Probes*

a. What is the desired volume flexibility ? *4350 cases per day +/- 100 cases per day*.

b. What is the current volume flexibility ? *4200 cases per day +/- 150.*

c. Identify ways to improve the volume flexibility, if the desired volume flexibility is greater the current volume flexibility.

Increase wrapper reliability, Improve tailsealing quality, speed up logsaw revolutions.

e. What measure could be used to evaluate the action steps selected ?

Downtime, quality defects reduced.

f. What is considered to be an acceptable rating ?

Downtime reduce by 10%, the total number of defects reduced by 10 %.

g. Evaluate action steps (Acceptable or Not Acceptable).

Examples of measuring results:

- % improved
- % increased
- downtime reduce
- changeover time reduce
- response to change
- cost savings

If your choices do not meet your goal, re-evaluate choices.

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