ABSTRACT

SOHAIL, SAQIB MIAN. Analysis of Productivity Measures and The Factors Affecting Accurate Measurement of Productivity. (Under the direction of Dr. Helumt Hergeth)

The purpose of the research has been to analyze the factors involved in the measurement of productivity at the plant level. The study was undertaken to determine the methods of measurement being used at the plant level and observe the accuracy of the system. This was achieved by conducting case studies at a weaving and apparel manufacturing facility. The results of the case studies have been significant enough to argue the relevance of current productivity measures being used for analysis by the U.S Department of Labor. Some of the factors such as medical costs, picks per shed that have not been considered in current productivity measures should be included to improve the accuracy of the productivity measures.

ANALYSIS OF PRODUCTIVITY MEASURES AND THE FACTORS AFFECTING ACCURATE MEASUREMENT OF PRODUCTIVITY

by
Saqib Mian Sohail

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APPROVED BY:

Dr. Abdelfattah Seyam **Dr. Michelle R. Jones**

Chair of Advisory Committee

Dr. Helmut H Hergeth

BIOGRAPHY

Saqib Sohail was born on June 22nd, 1981 in Lahore, Pakistan. His family moved to Karachi in 1986 and he has been living there since then. He completed his high school from D.H.A Model High School and got his Bachelor's degree in Textile Sciences from Textile Institute of Pakistan in 2003. He worked for a couple of years in the textile industry before leaving for Unites States for his Master's degree in Textile Technology Management from North Carolina State University in 2005.

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1.1 Introduction

The biggest problem at this time facing domestic textile employment is outsourcing of manufacturing to lower cost manufacturers around the globe. Processes become more labor intensive as products becomes more value added; from yarn to fabric. A major portion of higher labor costs can be balanced through savings on logistics and duties related to importing textile products. The labor costs can not be termed the only culprit in the low competitiveness of the textile industry.

1.2 Productivity Defined

Productivity measurements help comparing the progress of one company, firm or industry with another, locally or globally. Productivity is defined as a ratio of output divided by input, i.e., it answers the question how much output is achieved with a certain amount of input. Following the formula:

P = Output / Input

Higher productivity implies that more output is achieved with the same input or that same output is achieved with less input. Thus higher productivity means more efficient use of input resources. This basic formula is sufficiently abstract and vague to be generally acceptable without providing concrete results.

The key question when discussing productivity thus becomes "How should one measure outputs and inputs?" It might be done by virtue of revenue value, average units (per hour, employee, machine, etc) or opportunity cost. There are a lot of ways to define and measure productivity, some of which are mentioned below:

1. The quality of being productive.
2. *Economics.* The rate at which goods or services are produced especially output per unit of labor.
3. *Ecology.* The rate at which radiant energy is used by producers to form organic substances as food for consumers. (American Heritage Dictionary, 2000)

For a more business oriented definition:

Productivity: The efficiency with which output is produced by a given set of inputs. Productivity is generally measured by the ratio of output to input. An increase in the ratio indicates an increase in productivity. Conversely, a decrease in the output/input ratio indicates a decline in productivity.

And:

Productivity, n 1: the quality of being productive or having the power to produce [syn: productiveness] [ant: unproductiveness] 2: (economics) the ratio of the quantity and quality of units produced to the labor per unit of time, (WordNet®, 2003).

All these different definitions of productivity have one thing in common: there is an input and that there is an output. The critical issue that needs to be determined is what the inputs for a specific output are.

It is believed that the cause of productivity level is the direct result of factors such as:

- Choice of technology- Firms opting for machinery with narrow product focus, high output and low manufacturing flexibility or machinery with wide product focus, reasonable output and high manufacturing flexibility.
- Capital/Labor employed for cost/effectiveness- The amount of capital invested in a process is a vital input measure. The capital is in the form of purchases made for raw material, machinery and maintenance. The amount of labor per process or operation can be a good indicator of the efficiency of that process.
- The type and level of technical and managerial (organizational) know-how- This is related to the skill level of the operators and mangers in the organization. This makes a huge impact when the organization shifts from commodity products to specialized products.
- Timing of implementation- A lot of methods and standards can be introduced in an organization to make it run more effectively but the timing of implementation of such methods and standards is very important. Any such program can only be effective if the people involved are ready to accept the change. (Abbasi, 1992)

The calculation of productivity has long been a field of controversy with little value placed on the results because they seem to contain so many imperfections. Productivity remains one of the most elusive concepts in business and economic literature. It remains elusive because of a lack of definitive theoretical work-mainly at the firm level. (Cliff F. Grimes, Accel Team, 2003)

1.3 Department of Labor's Method of Measuring Productivity

Industry multifactor productivity measures, which were first released in 1987, relate output to the combined inputs of labor, capital, and intermediate purchases. Multifactor productivity is free of the effects of changes in the ratio of capital to labor and the ratio of intermediate purchases to labor, whereas labor productivity reflects these changes; hence, multifactor productivity is preferred to labor productivity as a measure of overall or total efficiency. However, due to the enormous data requirements for the measurement of capital and intermediate purchases, only a limited number of industry multifactor productivity measures have been published. (U.S. Department of Labor, Bureau of Labor Statistics)

1.3.1 Labor Productivity Measures

A better understanding of productivity measures can be achieved by investigating the current methods of measurement. For this purpose the U.S. Department of Labor provides data on the measurement systems being employed for official publications.

The indices of output per hour measure the changes in the relationship between output and the hours expended in producing that output. To calculate a labor productivity index, an index of industry output is divided by an index of labor hours:

where:

$$\frac{Q_t}{Q_o} \div \frac{L_t}{L_o}$$

$\frac{Q_t}{Q_o}$ = the index of output in the current year,

$\frac{L_t}{L_o}$ = the index of labor input the current year,

t = the current year, and

o = the base year.

For an industry producing a single uniform product or service, the output index is simply the ratio of the number of units produced in the current year divided by the number of units produced in the base year. Similarly, the employee hour index equals hours expended in the current year divided by hours expended in the base year.

More typically, industries produce a number of different products or perform a number of different services. For these industries, output is calculated with a Tornqvist formula:

$$\frac{Q_t}{Q_{t-1}} = \exp\left[\sum_{i=1}^{n} w_{i,t}\left(\ln\frac{q_{i,t}}{q_{i,t-1}}\right)\right]$$

where:

$\frac{Q_t}{Q_{t-1}}$ = the ratio of output in the current year (t) to previous year (t-1)

n = number of products,

$\ln \frac{q_{i,t}}{q_{i,t-1}}$ = the natural logarithm of the radio of the quantity product i in the current year to the quantity in the previous year, and

$w_{i,t}$ = the average value share weight for product i

The average value share weight for product j is computed as:

$$w_{j,t} = \left(s_{j,t} + s_{j,t-1}\right) \div 2$$

where:

$$s_{j,t} = p_{j,t} q_{j,t} \div \left(\sum_{i=1}^{n} p_{i,t} q_{i,t} \right)$$

and $p_{i,t}$ = price of product i at time t

The Tornqvist formula yields the ratio of output in a given year to that in the previous year. The ratios arrived at in this manner then must be chained together to form a series. If t = 3 and the base year is denoted by o, then

$$\frac{Q_t}{Q_o} = \frac{Q_3}{Q_o} = \left(\frac{Q_3}{Q_2}\right)\left(\frac{Q_2}{Q_1}\right)\left(\frac{Q_1}{Q_o}\right)$$

The resulting chained output index, $\frac{Q_t}{Q_o}$, is used in the productivity formula. The employee hour index for an industry with multiple products is calculated in the same manner as in the single-output case. (U.S. Department of Labor, Bureau of Labor Statistics)

The measures of output per hour relate output to one input—labor time. They do not measure the specific contribution of labor, capital, or any other factor of production. The measures reflect the joint effect of a number of interrelated influences such as changes in technology, capital investment per worker, capacity utilization, intermediate inputs per worker, layout and flow of material, skill and effort of the work force, managerial skill, and labor-management relations. (U.S. Department of Labor, Bureau of Labor Statistics)

1.3.2 Multifactor Productivity Measures

The industry multifactor productivity indexes calculate productivity growth by measuring changes in the relationship between the quantity of an industry's output and the quantity of inputs consumed in producing that output, where measured inputs include capital and intermediate purchases (including raw materials, purchased services, and purchased energy) as well as labor input.

A Tornqvist index is used to calculate multifactor productivity:

$$\ln\left(\frac{A_t}{A_{t-1}}\right) = \ln\left(\frac{Q_t}{Q_{t-1}}\right) - \left[w_k\left(\ln\frac{K_t}{K_{t-1}}\right) + w_l\left(\ln\frac{L_t}{L_{t-1}}\right) + w_{ip}\left(\ln\frac{IP_t}{IP_{t-1}}\right)\right]$$

where:

ln = the natural logarithm of the variable

A = multifactor productivity

Q = output

K = capital input

L= labor input

IP = intermediate purchases input

w_{k}, w_{l}, w_{ip}= cost share weights

The weights are the means of the cost shares in two adjoining time periods.

where:

$$w_i = \frac{(s_{i,t} + s_{i,t-1})}{2}$$

$$s_{i,t} = \frac{p_{i,t} x_{i,t}}{\Sigma(p_{i,t} x_{i,t})}$$

$p_{i,t}$ = price of input x_i in period t

The Tornqvist formula yields growth rates which are differences in logarithms. The antilogs of these rates are chained to form the index. (U.S. Department of Labor, Bureau of Labor Statistics)

1.4 Productivity Review

Data from the U.S Department of Labor show that labor productivity has been increasing thus, a corresponding reduction of labor costs is expected. However the industry continues to lose business on the basis of product cost. This leads to other areas that need to be identified as contributors for low cost competitiveness. Figures 1, 2 and 3 show the overall productivity numbers of the manufacturing industry including textiles.

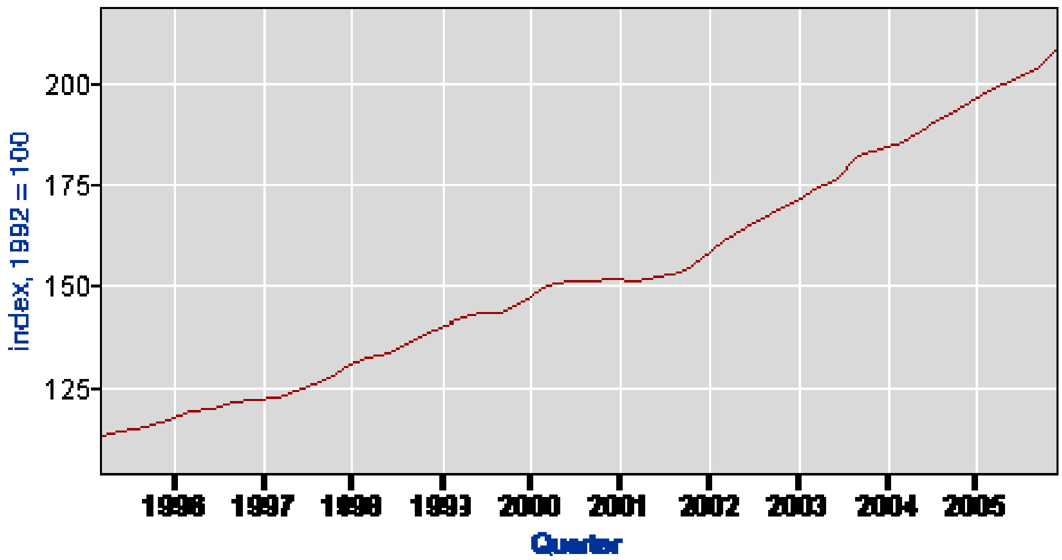


Figure 1: Out per hour
Duration: index, 1992=100
Measure: Output Per Hour
Sector: Manufacturing, Durable Goods

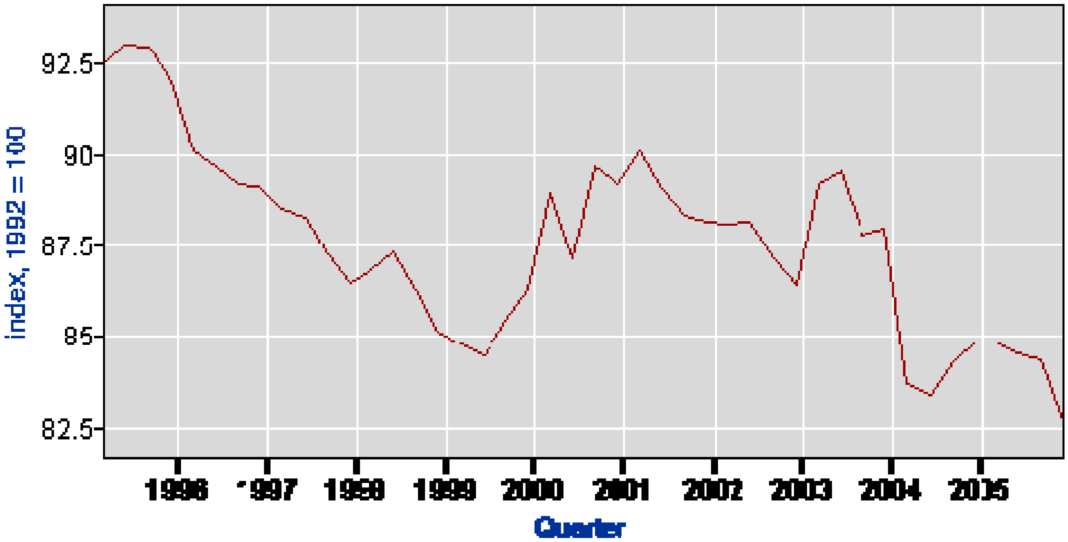


Figure 2: Unit Labor Costs
Duration: index, 1992 = 100
Measure: Unit Labor Costs
Sector: Manufacturing, Durable Goods

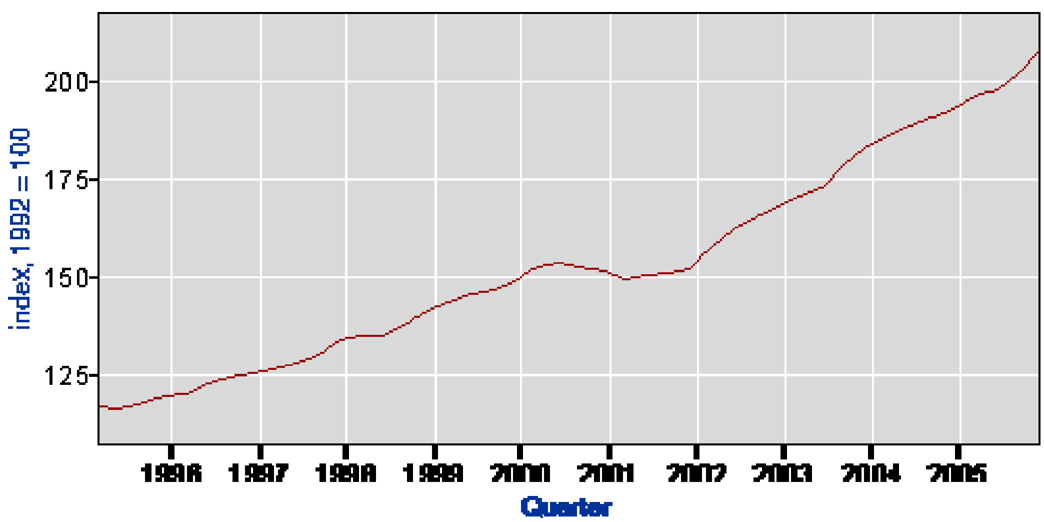


Figure 3: Output per Person
Duration: index, 1992 = 100
Measure: Output Per Person
Sector: Manufacturing, Durable Goods

Comparison of figure 2 and 3 shows that output has been steadily increasing but the reduction in unit labor cost is not as steady and the magnitude of increase in output is higher than the reduction in unit labor costs. One of the reasons could be the wage bargaining between employees and employers. It can be observed that the wages have not been increasing at a high rate during the period observed in figure 2 while productivity has been increasing at a good rate thus reducing the overall labor cost per output. It can be seen in figure 3a and 3b that overall wages have in fact been decreasing over time thus providing a higher rate of increase to productivity numbers.

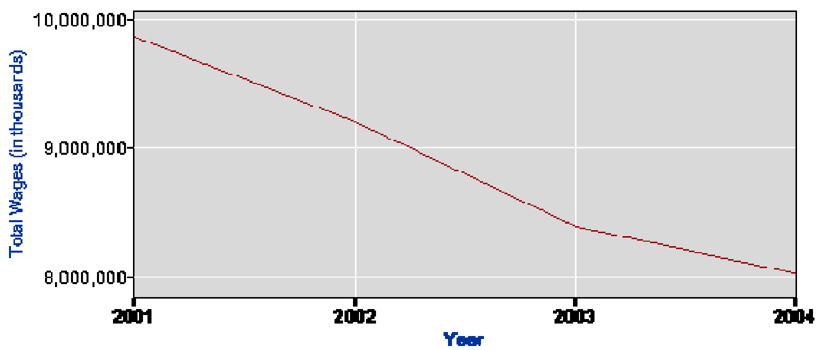


Figure 3a: U.S. Total **Industry:** NAICS 3132 Fabric mills
Type: Total Wages (in thousands)

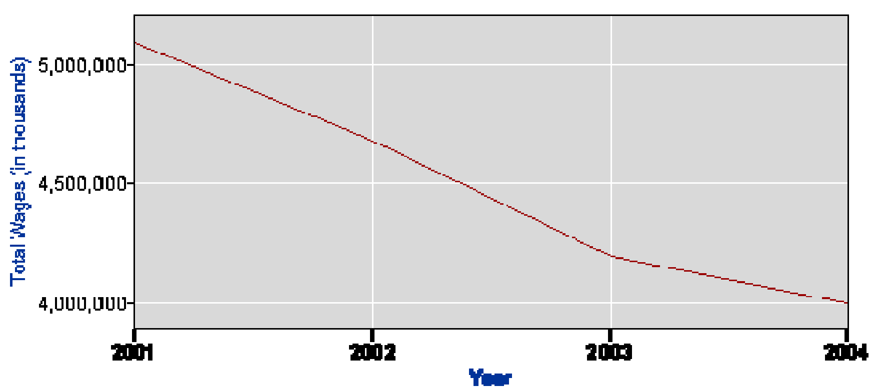


Figure 3b: U.S. Total **Industry:** NAICS 313 Textile mills
Type: Total Wages (in thousands)

The above figures (U.S Department of Labor) are further supported by numbers of the textile industry that shows similar trend in the productivity area. The following figures 4 and 5 use SIC codes to represent the productivity numbers till 1999, after 1999 the system has switched to NAICS method of categorizing industries which was used for figures 1, 2 and 3.

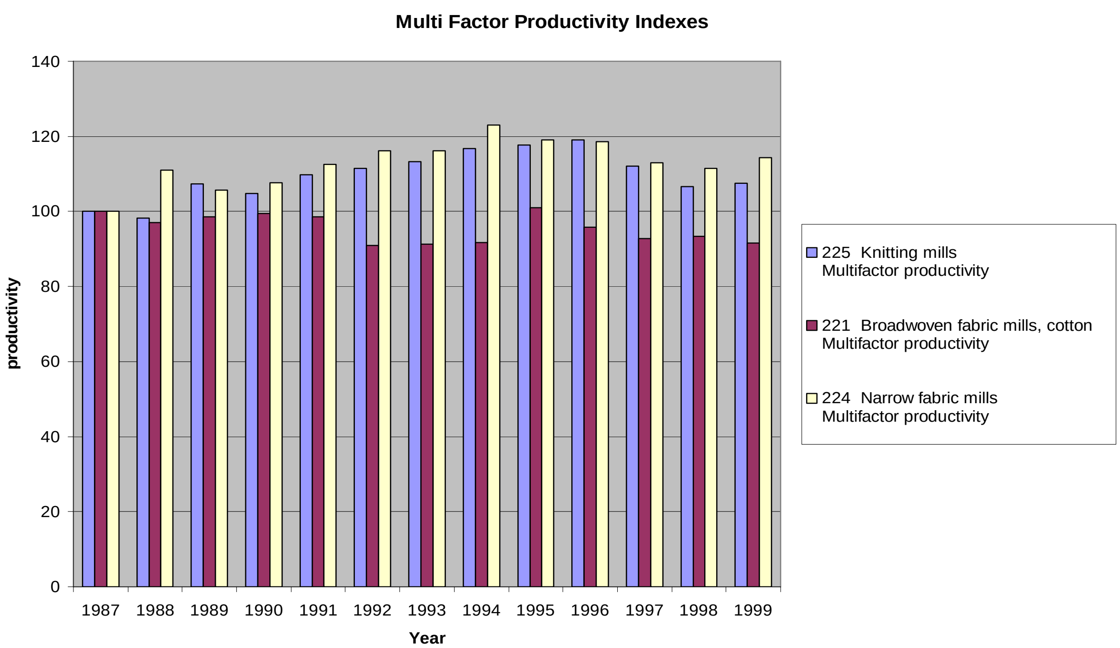


Figure 4: Multi Factor Productivity

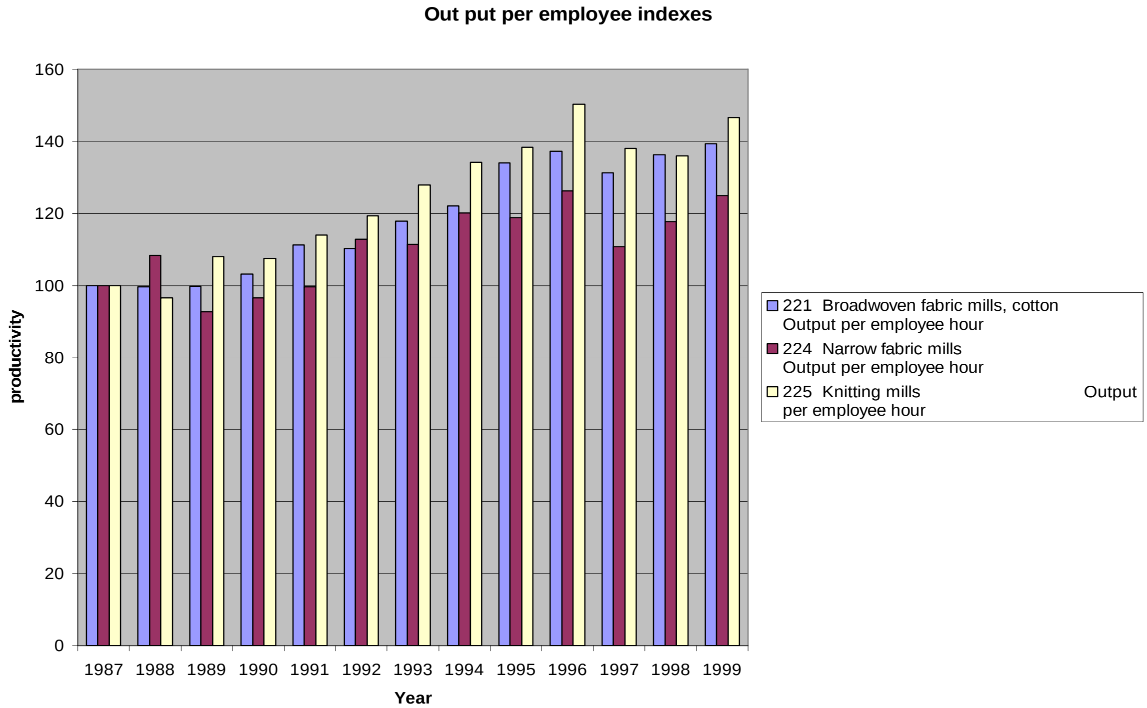


Figure 5: Employee Output (U.S. Department of Labor)

NAICS is the first industrial classification system used in the United States to employ a unified economic concept to define industries. Under the new system, industries are classified on the basis of their production or supply function—establishments using similar raw material inputs, capital equipment, and labor are classified in the same industry.

This approach creates more homogeneous categories that are better suited for economic analysis.

The following primary concepts were used in the development of NAICS. First, a production-oriented conceptual framework was used—as described earlier, establishments engaged in similar production activities are classified together. Second, new categories in

NAICS focus on emerging industries, services in general, and industries that produce advanced technology.

Third, as much as possible, continuity with the former system was maintained to avoid breaks in time series. (John B. Murphy, 1998)

1.5 Productivity in Textiles

Every industry goes through its ups and downs with the textile industry being no exception. The misconception lies in the way the productivity problem is perceived and solved. This misconception is caused by the method of measuring productivity and by considering productivity as a major hurdle in improving competitiveness. In the case of U.S textile industry it is the method of identifying the problem that is a major hurdle in solving the bigger problem of competitiveness.

"Much of the U.S. textile industry is in dire straits. Despite record productivity gains, massive modernization programs and the development of numerous innovative products, the industry finds itself in one of its deepest depressions ever."(Devin Steele 2001)

The above statement is directly relating productivity gains to improved profits that could not be achieved hence the industry is facing a downward trend. As mentioned earlier in this paper, productivity has a direct relationship with cost efficiency and an increase/decrease of one should have a major impact on the other. According to this, record productivity gains in the industry should have been rewarded with efficient production, lower costs, and competitive advantages.

This leads back to the points raised in the beginning of this paper. If productivity gains are very high then resultant cost reductions should be observed. This further provides reason to take a closer look at the measurement of productivity to investigate if the high values of productivity are accurate or not.

1.6 Product Complexity

It is important when analyzing a textile company to have information about product complexity or the difficulty to produce a certain product. One example of product complexity is shown in table 1 where the products are woven fabrics and the measurement of the product complexity is done by comparing stop levels. There is more than one method of analyzing product complexity as some companies use internal methods like points per loom as is seen in Case study 1 in section 5.1.1.3.

Table1: Product Complexity versus Stop levels

Style	Actual Stop	Standard Stop
	Level	Level per CMPX
Easy	2.29	1.83
Easy	2.59	1.98
Easy	2.27	2.3
Easy	5.46	3.56
Difficult	10.12	6.22
Difficult	12.62	9.2
Difficult	8.15	6.3
Difficult	9.97	8.8

(Batson M. D.1997)

1.7 Management's Concepts of Productivity

This part of the paper deals with the management's point of view of productivity, its measurement and benefits. Productivity of any process has always been related to direct labor input relative to output, which is correct but not complete. The role that the middle and top management plays in converting input into output has recently been highlighted especially by Peter Drucker.

Peter Drucker has been instrumental in improving the efficiencies of manufacturing in United States. While the focus in a manufacturing industry is on the productivity of labor less emphasis is given to the "The productivity of the new workforces." (Drucker 1993)

The new challenge facing the post capitalist society is the productivity of knowledge workers and service workers. Improving productivity of knowledge workers will in fact require drastic changes in the structure of the organizations of post-capitalist society and in the structure of society itself.

"Forty years ago people doing knowledge work and service work were still less than one-third of the workforce. Now such people account for three-quarters if not four-fifths of the workforce in all developed countries – and their share is still going up. Their productivity rather than the productivity of the people who make and move things is the productivity of a developed economy. It is abysmally low." (Drucker 1993)

Peter Drucker identifies knowledge worker productivity as the "biggest of the 21st century management challenges." His view of the consequences of ignoring the primacy knowledge is Draconian: "In the developed countries it is their first *survival requirement*. In no other way can the developed countries hope to maintain themselves, let alone to maintain their leadership and standard of living….The only possible advantage developed countries can hope to have is in the supply of people prepared, educated, and trained for knowledge work…. Fifty years from now—if not much sooner—the leadership in the world economy will have moved to the countries and to the industries that have most systematically and most successfully raised knowledge-worker productivity." (Drucker 1999)

The above statements of Peter Drucker can be used to help improve the competitiveness of the textile industry. It is imperative that textiles industry requires people at every level who have a deep understanding of the consequences of their action. Every one participating in the process of manufacturing has to become a productive knowledge worker to continuously improve processes.

1.8 Why Measure Productivity

The word 'Productivity' often sparks an argument that the U.S has gained a lot in productivity and that it is not the problem that has led to the decline of the industry. Productivity is not only a tool to represent the outputs of a process but more can be achieved by using productivity data. The purpose of measuring productivity is found in the potential rewards mentioned below:

- For strategic purposes in order to compare the global performance of the firm with competitors or similar firms.
- For tactical purposes, to enable management to control the performance of the firm via the performance of individual sectors of the firm either by function or product.
- For planning purposes, to compare the relative benefits accruing from the use of differing inputs or varying proportions of the same inputs.
- For internal management purpose, such as collective bargaining with trade unions. (Cliff F. Grimes, Accel Team, 2003)

It is generally accepted in the U.S textile industry that productivity of manufacturing processes is high compared to manufacturers around the world. This is supported by various studies, one of which is quoted below:

"For the last 120 years, productivity in making and moving things has risen in developed countries at an annual rate of 4%, a 45-fold expansion overall. Now these gains are unraveling, but not because productivity in making and moving things has fallen. Contrary to popular belief, productivity in these activities is still going up at much the same rate."(Drucker 1991)

It is very important to investigate the measures of productivity of the textile industry as it sometimes reflects only single process efficiency and not the total productivity considering all processes involved. It is also necessary as most of the management related studies consider manufacturing processes as similar to each other. This may not be true in the case of the textile industry as the processes involved are affected by a high number of variables compared to any other industry.

“Investment in yarn spinning machinery and technology has made the U.S. textile industry the most efficient in the world. In fact, productivity gains in that sector have been surpassed only by the U.S. electronics and computers industries.” (Gaylon Booker, 2001)

High productivity is very important in order to achieve cost-effectiveness but the problem lies in evaluating the process of measurement and interpretation of the measurements. The problem is how we evaluate the true productivity of any process. Multi-tasking in the various textile manufacturing processes has further complicated the calculation of actual cost of a product. It is very important to separate the labor cost of a specific product from the total cost of labor. Labor cost varies depending on the type of the product; if a complex new product is introduced in the manufacturing mix then more labor hours are expected to be spent to manufacture that product than a regular commodity product. (Company 1 Interview)

The point is further explained by Bridges who gives a fundamental reason for measuring productivity:

"Some type of benchmark (standard, average, mean) should be determined, if none exists. How can you be sure of how much is being saved if you do not have a baseline?" (Bridges, Bernisha M., 1992)

Peter Drucker has put it in a more general way:

"Without productivity objectives, a business does not have direction. Without productivity measurement, it does not have control." (Drucker, 1974)

So in order to analyze the textile industry it is very important that proper measurement analysis is used to validate the current measurements system or provide a system that better reflects the condition of the industry. That system would also be able to indicate the cause of the problem(s) and give indications to solve them to improve the process. Bridges states,

"The keystone to implementing productivity improvements is putting everything in measurable terms." (Bridges, Bernisha M., 1992)

It is important to understand the measurement outputs of productivity before productivity itself can be measured. Without understanding the measurement process steps of process improvement can not be taken. Productivity improvement is tied to productivity measurement, which is tied to the measurement of the work. The first step is measuring work.

A measurement system serves two basic functions for productivity improvement programs. First, people perform to measures when rewards are linked directly to those measures. Productivity measurement can itself be a productivity improvement program. Keeping score can lead to improvement in the score; we must keep score on the right factors to meet company goals. Second, the value of planned programs can be estimated only if specific measurement is possible. The effect of managerial changes can be determined subject to the net result on outputs and inputs as given in productivity ratios. (Everett E. Adam, Jr., James C. Hershauer, William A. Ruch)

It is very important that accurate measurement is done at plant level and this paper attempts to validate the productivity measurement system being used in the textile industry. This is a major concern because there is no evidence of use of a unified productivity measurement system.

Different measurement definitions and techniques are surveyed and researched to determine the accuracy of the measurement techniques as well as identify a system that could be used as a standard for the textile industry. This can be used more effectively to measure the competitive impact of productivity.

2 Objectives

The literature review provides evidence that further research is required to analyze productivity measures and factors affecting the measurement process. The following specific objectives served as the basis for the analysis;

1) Identification of the influence productivity has on the textile industry and a specific company.

2) Analysis of the available productivity data and the measurement process for productivities in the textile industry.

3) Analysis of the relationship between productivity and cost structure of the end product.

3 Procedure and Methodology

The purpose of this paper was to research published productivity data and compare it to current company practices in textiles with a focus on labor productivity using case studies. The scope of this research included mainly weaving operation case studies.

Productivity data of U.S Department of Labor was analyzed as a starting point for the project. This Department of Labor method was compared to those used at the operations level in the textile industry. The research analyzed the published productivity data and prepared questionnaires to validate the methodology.

Case studies and plant visits were used to identify how productivity is measured at the plant level. Plant visits and interviews were used to compare the plant productivity measures with those of the Department of Labor.

4 INVESTIGATION OF PRODUCTIVITY MEASURES

4.1 Introduction

The U.S textile industry shrinks rapidly with increasing outsourcing of manufacturing, and the run size or batch size of the manufacturing processes is getting shorter to accommodate quick style changes. The product mix is becoming more complex with an increasing number of designs corresponding to lower quantities per design. This complex product mix is quite contrary to the highly efficient economies-of-scale manufacturing setups in the industry that were designed to produce large quantities efficiently and cost effectively.

Today's product mix requires a flexible short-run setup, which often is not compatible with the long-run setup for consistent production most manufacturers have. Therefore style changing costs are high, and with a downward trend in the domestic textile industry it is difficult to justify investment opportunities aimed at improving setup costs and style changes, which would make setups compatible with a complex product mix. These costs are high because of the corresponding impacts on factors such as number of stops and stops per minute (in a weaving shed) with change in style difficulty. This point is explained in section 5.1.1.3 of this paper. This unfortunately greatly impedes U.S textile manufacturers' ability to compete on price.

The current economies-of-scale setup increases waste during short runs thus increasing product cost. The new style that comes into the manufacturing mix initially runs inefficiently as operators learn to handle the new style. This point is explained in section 5.1.1.4 of this paper. Economies-of-scale setups also do not allow manufacturers the flexibility of design changes over shorter runs. As equipment has become faster and more productive it takes longer to change designs and for some narrowly specialized machinery makes it difficult to handle different product types.

Most productivity measures however favor economies-of-scale production setups. Equipment productivity is frequently only measured and advertised as output, maximum output, or more correctly as output per specified input (typically labor, sometimes energy) during maximum speed. Higher speed, productivity, and in some cases energy efficiency traditionally were the main sales arguments in equipment sales. In many cases productivity is expressed as labor productivity expressed in terms of output per labor hour or in some cases as number of machines per operator. If we can increase the number of machines per operator then it is an indicator of increase in productivity of the labor. Consequently labor productivities in the United States and other industrialized countries are extremely high today.

4.2 Productivity Measure

In the most general sense productivity is defined as Input/Output. Total productivity considers all inputs, typically expressed in cost numbers, while partial productivities look at output relative to a specific input category, e.g., labor hours. Productivity measures serve as an analytical tool to evaluate and compare how much output can be produced with a given input of specific production factors. The output is always measured in terms of a physical product or service unit, e.g., yards, pounds, dozens, etc.

If output is measured not in physical units but in terms of money (e.g., profit or sales volume) the measure is no longer a productivity measure but a profitability measure. Profitability can be expressed as a ratio of profit relative to any kind of input, e.g., per employee, operator hours, invested capital, sales, or any specific type of cost.

Profitability however is a purely financially based measure and is heavily related to the sales price of the output. This makes profitability a good overall measure of economic success of a company or business unit, but it also depends on the economic environment and competition, issues that are beyond the control of manufacturing operations.

Efficiency on the other hand can be focused on specific operations in a manufacturing setting. This measure is usually used to provide information about end of the line processes, for example; loom efficiency in a weaving operation. Efficiency generally looks at actual production compared to standards. These standards can be based on historical data or theoretical assumptions or on the production of similar products. Efficiencies can be used to analyze run times versus downtimes, yields of raw material utilization, and they are useful in capacity planning as they provide actual through-put times of all processes.

All three categories of measures are relevant in running a company, but they serve different purposes. All three aid in analyzing a company and can give direction and feedback for improvement of the overall competitive position of the company. Productivity measures specifically help in analyzing the operations side of a company or business. Therefore it is important to eliminate market influences on prices etc., and this is why productivity output is always measured in physical units rather than money. Of course this makes it much more difficult to compare productivities of different businesses or industries. At the macro level this leads to using productivity indices, which on a practical level make productivity measures less tangible for use at the plant level. There are also some limitations to comparing indices of different regions or industries. (Saqib Sohail & Helmut Hergeth, 2006)

4.3 Goal of Productivity Measures

Productivity measures focus on improving operations in a manufacturing plant or service company. The focus of this paper is on manufacturing settings. The goal is to increase output while keeping the input constant or reduce input for a given output. By using specific input categories, productivity ratios can be tailored towards a measure that can be influenced by activities in a specific operation.

Specific purposes for productivity measures include:

- For planning purposes, to compare the relative benefits accruing from the use of differing inputs or varying proportions of the same inputs. It helps in improving operator productivity as it analyzes the operations performed by the operator. It provides information on output per labor hour invested in the process. This provides information to improve machine productivities that lead to capacity planning. The improvement in capacity planning helps achieve higher throughput with existing capacity thus higher productivity levels.

- For strategic purposes in order to compare the global performance of the firm in specific operations with competitors or similar firms. This also lets the management compare different product lines within the same organization or compare different plants.

- For tactical purposes, to enable management to control the performance of the firm via the performance of individual sectors of the firm either by function or product. Substitution factors are one of the most important in productivity measurement. Factors like raw material, operator skills and machine investments can be substituted and measurements done to observe the differences and perform comparative analysis. An example of this would be comparing productivities if we substitute raw material quality. The effects of this change will be seen in machine operations as the frequency of breakdowns will definitely change keeping everything constant. This is further elaborate ahead in the paper in section 5.

- For internal management purpose, such as collective bargaining with trade unions. The measures help perform operator evaluations as the performance can be compared to historical data or standards set for that operation using productivity measures.

5 Case Study 1: Company 1

As part of the research a case study was conducted at Company 1 to analyze their productivity data and methods, and compare them to the measures of U.S Department of Commerce. Company 1 has a spinning facility as well as weaving facility to produce finished woven products in-house.

5.1 Outcomes of the Case Study

5.1.1 Factors Affecting Productivity

The case study investigates the factors involved in measuring productivities in a complex product mix and seeks to answer the question why higher labor productivities do not result in higher price competitiveness. The goal is to highlight the most significant factors influencing productivity in a complex product mix environment and to explore alternative productivity measures that may aid in optimizing production using available manufacturing resources.

One of the advantages of productivity measures over profitability or efficiency measures is the ability to focus on specific aspects of an operation. To properly direct this focus, it is necessary to single out the main factors affecting overall manufacturing productivity in a complex product mix. The following factors can be viewed as significant in the measurement of and influence on productivity in a complex product mix manufacturing situation:

5.1.1.1 Labor/Operator Time

The most frequently used productivity ratios evaluate output relative to labor input, e.g., per operator hour or per operator. These calculations are necessary to help in planning the necessary labor resources, and they are also used to evaluate how efficiently labor resources are used. However there are serious limits when it comes to comparing labor productivities of different product mixes.

In Company 1’s manufacturing facilities for woven fabrics, product complexity as well as the speed of style changes is very high. One of the problems in measuring labor productivity is that the measurements need to take multi tasking of labor into account, because the plant is running many product types simultaneously. Some of the products are commodity items while others may be specialty or new products (e.g., a complex satin weave) that require more supervision. Operators are usually responsible for more than one machine and they have to go back and forth on the assigned machines.

In this scenario the operator tends to spend more time on the difficult product than the commodity product. Costing of a product should be based on activity performed by the operator on a certain product type rather than being distributed over all products running in the operations facility. For planning purposes, averaging historic labor requirements over two or more product types may be sufficient. However, comparing labor productivity of different plants becomes quite challenging as they may have different product mixes.

In a commodity product scenario, labor productivity is typically improved by introducing automation into the manufacturing process. The cost of such an investment is then absorbed by improved productivity and increased production in a typical economies-of-scale scenario. However, non-commodity products are not as easily automated which leads to higher investment costs for automation and/or to reduced or limited improvements in productivity. Additionally non-commodity products tend to serve smaller markets, so that the increase in production is either not desirable because of its impact on prices, or simply cannot be absorbed by the market. This dissolves the economies-of-scale scenario. However, labor productivity is used heavily to justify investments in labor saving automation, and many cost competition analyses focus on labor productivity, praising such investments in high production speed equipment.

Within a typical textile plant today there are not just a few, but hundreds or thousands of different styles, and many of them may run simultaneously in the same plant as is the case in Company 1. As these products and styles are changing, it is necessary for one operator to handle different styles at the same time and changing styles over time. In such a situation not the fastest ("most productive") but the most adaptable operator tends to be more appropriate. In this case, traditional productivity measures will provide constantly varying results depending on constantly varying products, and it might be more appropriate to try to measure a rate of adaptability.

As a sidebar it should be added that the issue of operators multitasking can also provide a problem in labor cost allocation onto these products. Usually they are just equally divided over all the products manufactured in the plant, which means they are allocated like overhead in a standard cost environment. This easily leads to incorrect labor cost allocation, magnified by the fact that many textile and apparel companies then use direct labor cost to allocate various overheads. Such cost misallocations create a major problem in a cost competitive setting.

5.1.1.2 Employee Turnover

Employee turnover is a very important issue facing today's textile industry and it affects Company 1 similarly. It was found during the case study that employee turnover has an influence on traditional operator productivity because of the learning curve new employees go through, as well as on product cost due to increased recruitment and training cost. The increase in labor wages from standard average wages in the plant is found to be in the range of 40-45% when an employee is re-hired for the same job. This increase in wages is primarily based on employee's concerns of job security.

If a company gains the reputation of having high turnover rates this may additionally result in the need to offer more attractive compensation packages. The same is true for any other factors that cause a perception of instability in the manufacturing environment or in the employment situation.

It was observed during the case study of Company 1 that textile industry companies are faced with the issues of a perception of an instable environment. This is due to the continued and well-published overall decline in the industry's employment levels. While this typically would result in a labor surplus in traditional textile regions, it also leads to the best skilled operators seeking employment outside of the textile and apparel industry with little chance of getting them to return. However, more complex product mixes require higher skilled operators as they need to be able to handle a range of changing styles and products, and the number of these highly skilled workers is shrinking which is making the hiring process difficult for the industry. At the same time a sense of insecurity develops among the operators when they observe the high employee turnover. This may keep them on the edge and looking for permanent options outside of the industry, keeping them from giving 100% effort in their current position.

The negative effect that employee turnover has on operator productivity is magnified in a complex product mix environment. It was also observed during the case study of Company 1 that training of new operators tends to be more expensive and takes longer due to the higher skill requirements in a complex product mix, and during these training times productivities tend to be lower. This can also be seen in section 5.1.1.4 in figure 6 in this paper.

5.1.1.3 Product Complexity

An individual product can be more or less complex. The less complex a product is, the higher the productivity rate. In Company 1 the learning curve for simple products takes less time for operators to achieve an optimum level. Less complex products can also be automated more easily, and more complex products tend to be more error prone because of their higher number of operational steps. This leads to a lower yield of first quality output and to more frequent interruptions of the production process. Less complex products also tend to result in better raw material utilization. Machines producing more complex products tend to run slower, mostly as machine parts have to move more in order to create a complex pattern or style.

Indirectly, in Company 1 complex products tend to be produced in lower numbers than commodity products, which reduces the opportunity for achieving optimum levels in the learning curve and makes automation investments less attractive because the cost savings through the automation may not reach break even quantities.

Waste is another factor that is affected by a complex product. An example for this would be the difference between a complicated jacquard design and a plain sheeting fabric. If there is a major fault during the production of the sheeting fabric no more than 1-2 inches of the fabric has to be removed as waste from either side of the fault. According to the case study of Company 1, for a normal sheeting fabric the cumulative faults per million picks are 1.5. If for example, a jacquard fabric that has a design that completes on 6-7 inches and a major fault occurs on the 5^{th} inch, the whole length of the design becomes waste thus reducing the productivity of the process. The amount of waste depends on the position of the fault and the length of the design pattern repeat. This significantly increases the amount of waste, thus reducing productivity. Additionally identifying and possibly correcting a fault within a complex design is not as easily possible and takes more time.

It has already been studied that with increasing product complexity the cost of production increases. Table 1 in section 1.6 shows that how stop level increases with change in product type from an easy style to difficult styles that has also been observed in Company 1. Complexity in company 1 is defined as the number of stop levels above average stop levels of a standard commodity product such as 250 count cotton 60 warp, 60 filling with 122 ends and picks per inch. The average total stops per hour for a commodity style are in the range of 1.9 to 2.4. A complex product in Company 1 is 230 count cotton sateen that has stops per hour in the range of 5.6-6.5. Also in Company 1 the use of points per loom defines a difficult product. The points per loom are calculated by using stop level data (this calculation was not provided by Company 1). The increase in points per loom shows the difficulty of the style as seen in Table 2. The points are compared to standard points calculated using historical data of similar products (see Appendix C).

Table2: Product Complexity versus Points per loom

Style	Actual points per loom	Standard points per loom
T-3F Luxury (Easy)	10.98	11.43
T-3J Luxury (Easy)	3.38	7.79
T-97 230 count Cotton Sateen (Difficult)	284.36	293.64
T-3K 180 MC Blend DP 40/60 (Difficult)	71.1	97.72

(Based on data in Appendix C)

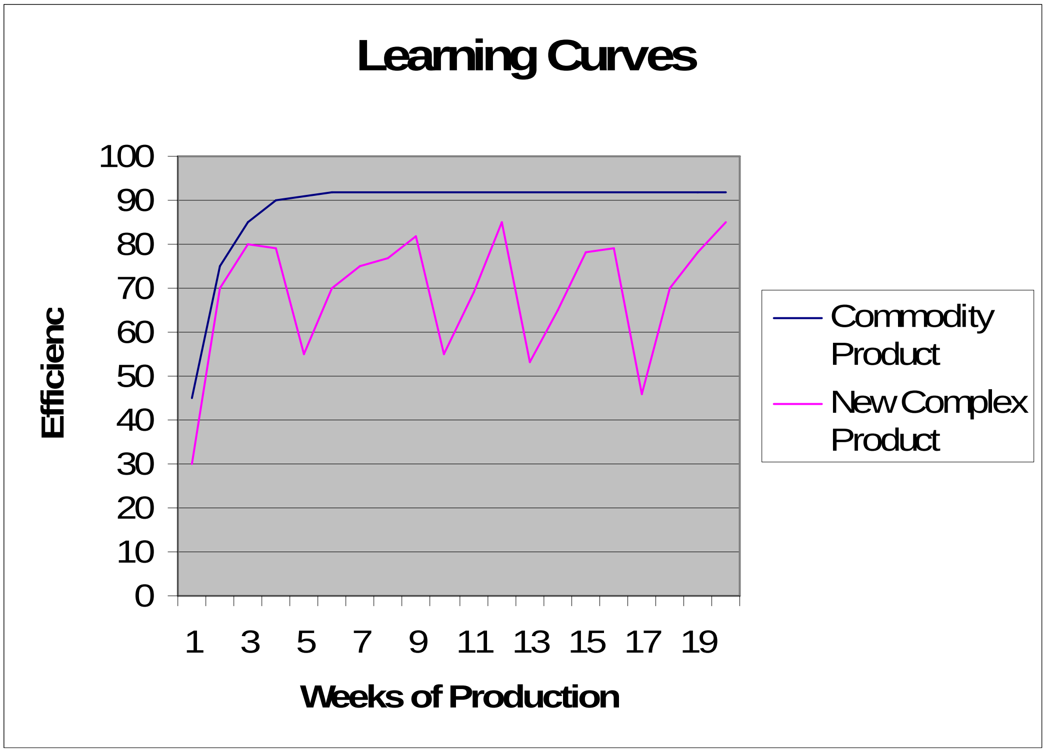
5.1.1.4 Product Mix

Product mix is one of the most important factors influencing productivity in a complex product mix. The case study of Company 1 showed that manufacturing productivity tends to decrease for a number of reasons as product mix complexity increases.

As shown earlier labor productivity will go down as an operator supervises several products of different product complexity. It was found during the case study of Company 1 that a complex product mix requires higher skill levels for the operators as they need to be able to run a variety of products and handle more style and product changes. Running multiple products and changing products over time increases production interruptions due to stoppages or process quality problems (e.g., yarn breaks, missed picks, etc.), and due to an increased number of setup changes. Table 1 in section 5.1.1.3 also provides an example of stop levels increase with style changes.

When styles of products change, the equipment typically has to be set up differently, which depending on the type of change can lead to long downtimes. After the equipment has been set up for the new style, the equipment has to be calibrated and first samples have to be tested. The more automated and faster the equipment is, the more sensitive the calibration, and in many cases the more complicated the setup of new styles. This interruption causes downtimes which reduces productivity. At the same time, setup, calibration, and testing require raw materials, so an increase in number and variety of styles will reduce the raw material yield for the company. Even simple changes like a minor change in yarn number for the filling yarn will require resetting, recalibrating, and testing. Changes in weave structure or warp yarn are even more complex. Any change in structure or material choice can cause increase in stop times. This increase in stop times results in a reduction of overall productivity.

In addition to the interruption of the production process itself, starting the production of a new style requires some adjustment on the equipment and some gaining experience with the new product by the operator. Each time a new product starts up the operation goes through a learning curve, while a consistent commodity product will maintain a high level of productivity (see Figure 6). The introduction of new products provides a new challenge for the operators who go through another learning period to become efficient in producing the new products. The data used has been extrapolated over 20 weeks in figure 6 using data of one week from company 1. This data has been extracted from Appendix B where the weekly production report shows the results of various fabrics manufactured during that week. Data for complex and changing products was extrapolated by using efficiency data from five (5) different products that were described by the company 1 manager as complex. Based on the total yardage the products had run and the feedback provided by the company 1 manager, the efficiency was assigned to a corresponding week in figure 6. Five (5) different that actually ran simultaneously were put into sequence for figure 6 to show the effect of introducing new complex products. The complex products can be seen with lower efficiencies compared to their standard efficiencies calculated by company 1. The new products being run in the Appendix B were highlighted by company 1 during visit of company 1. The actual efficiency of these products is used in figure 6. For the commodity product the end-efficiency of week 1 was extrapolated over 20 weeks in figure 6.



(Saqib Sohail & Helmut Hergeth, 2006)

Figure 6: Learning Curves for Commodity and Complex Products Introduced In the System

In an interview during the case study of Company 1 it was stated by JN of Company 1 that for decades the emphasis of new equipment has been increased speed, production, and a higher degree of specialization. Due to vast discrepancies in hourly wages between industrialized and developing countries, increased machine productivity focused on reducing labor requirements, which results in a larger number of machines being assigned to one operator. Thus the chances of one operator simultaneously supervising several different operations and styles have drastically increased.

As a result of lower labor costs in parts of the world, U.S. manufacturers began to outsource their commodity products to lower wage regions, while trying to manufacture complex products in-house with capabilities of mirror manufacturing their commodity products. This has a negative effect on average productivity because the highly automated mass production equipment in the U.S. is not designed for an increasing frequency of product style changes.

5.1.1.5 Raw Material

Another factor was observed during the case study of Company 1 that has significant influence on manufacturing productivity is the raw material used in the process. It was observed during the case study of Company 1 that higher quality raw materials make processing easier, result in fewer errors and stops, and will therefore lead to higher productivities. The case study of Company 1 showed that efficiencies of the weaving operation can go down by as much as 25% with a change from normal cotton to organic cotton for the same style end product (see Appendix B). If a better quality raw material is substituted then productivity goes up as break downs decrease. The problem with this is that the cost of the raw material tends to go up as well as the raw material quality improves.

The case study company 1 also showed that in order to reduce setup times, it may become desirable to use the same raw materials for different products, what requires that the raw material quality level for the most demanding product or style becomes the standard for all or many products. Alternatively a company might try to use specific raw material qualities for each product or style to reduce raw material costs. This will increase setup costs, may increase raw material waste (i.e., lower yield), and will increase the complexity and cost of raw material storage and administration.

5.2 Discussion

Productivity measures as an indicator of competitive strength need to be considered with caution. Using labor productivity to compare different companies or industries is fairly meaningless unless they are producing very similar product mixes and calculate their productivities in the same fashion. This point is further established in the paper with a case study analyzing cost structures in section 6 (Case study: Cost Analysis of single pick compared to multiple pick insertion per shed).

On the other hand the comparative measure might not be used for the whole process but to provide relevant information on specific portions of a process when new complex products are introduced into the system. Specific productivity measures may help to identify sources of inefficiency within the system that slow down the system due to the introduction of a new complex product.

When focusing on the system at a very broad or aggregate level productivity measurements will provide an insight into production capabilities of the system. For such a capacity analysis it is necessary to consider and include setup times, downtimes, etc. However, when comparing productivities to evaluate labor efficiency or the efficiency of other inputs it is relevant to compare only the run time efficiencies of the new complex product with any commodity product. This way the measure does not include any style change times or setup times incurred when the new complex product is introduced since they are outside of the roam of control for the operator.

Within a complex product mix environment it may however be quite relevant to analyze the productivity of setup changes to identify areas for improvement. A general comparison of setup productivities for commodity products versus complex products is not necessarily useful just as comparing the productivity of setup changes in a plant producing extremely long runs of the same product with a plant running many short runs is not necessarily beneficial. This is relevant because the product mixes being run at the plants may be different and affect the measurement of productivity because a sateen fabric would have different stop levels than plain sheeting fabrics. In these cases the specific product mix needs to be analyzed to determine which areas of the process are most critical to the overall success of the operation because if a plant is running more of one kind of a product then the setup changes are relatively lower than a plant that is running a homogenous mix of different products. Specifically designed productivity measures for these aspects can then help in identifying areas that are candidates for improvement such an example is shown in figure 7.

Type of output measure	*Type of input measure*			
	Labour	*Capital*	*Capital and labour*	*Capital, labour and intermediate inputs (energy, materials, services)*
Gross output	Labour productivity (based on gross output)	Capital productivity (based on gross output)	Capital-labour MFP (based on gross output)	KLEMS multifactor productivity
Value added	Labour productivity (based on value added)	Capital productivity (based on value added)	Capital-labour MFP (based on value added)	-
	Single factor productivity measures		*Multifactor productivity (MFP) measures*	

Figure 7: Different Measures of Productivity (Paul Schreyer and Dirk Pilat *2001)*

The goal of productivity measures is not to reduce the complexity of the product mix – a complex product mix is usually dictated by the market or makes the products particularly attractive to the market. Rather the goal is to reduce process complexity while maintaining increased product mix complexity. This can be achieved if more emphasis is put on the productivities or in this case efficiency of setup times as it seems to be the major cause of concern in the complex product mix.

The method of productivity measurement at Company 1 is based on comparison analysis of efficiencies and analysis of stop levels. Company 1 has derived a standard formulation that provides numbers for a certain fabric type and the corresponding estimated stop levels. The estimated stop levels are based on historical data available and includes tolerances. The comparison of actual efficiencies of the operations is done with standard calculated efficiency of the operation. Stop levels are similarly compared to the standards and analyzed to observe differences from standard.

There is a wide range of productivity measures, mostly distinguished by the type of input factor considered. These productivity measures are very useful in identifying areas for improvement and providing meaningful performance feedback at different levels of an enterprise. Productivity measures at a more aggregate level can provide information on the substitution effect of different input factors, leading to improved input factor allocation. Productivity measures are not useful in providing meaningful comparisons of commodity product manufacturing plants with complex product mix plants.

In the complex product mix scenario productivity measures should focus less on manufacturing and labor productivity and more on productivities evaluating issues of specific relevance to complex product mixes, e.g., productivity of setups, etc. Relevant labor productivity analysis in these cases is better reflected by the approaches towards knowledge worker productivity. Using traditional labor productivities may lead to suboptimal investment decisions as manufacturing efficiency is not the only relevant factor for changing complex product mix scenarios.

The criterion that is used to measure and solve productivity problems for a normal manufacturer running commodity styles over a long run, i.e., large batch sizes, cannot be applied to a complex product mix situation such as Company 1. One of the reasons would be that the cost structure at Company 1 is not activity related and it does not help determine the labor cost for specific operations, which in the end results in inaccurate calculation of labor productivity. The labor cost is not operation or activity related. The cost should be preferably distinguished for amount of time spent on a certain product. If more time is spent on a complex product then a commodity product then more of the labor cost should be assigned to the complex product. In the current system cost is divided over all products, which might not be the most accurate way to calculate cost in such a scenario. The usual labor hours observed to determine productivity may not be the issue in this scenario

It is to be expected that Company 1 will show lower productivity levels compared to a plant running commodity products when conventional productivity measures are used. These productivities cannot be compared unless both plants are measured using similar inputs and outputs while running similar products. This requires a comparative analysis where the inputs and outputs take into consideration only the production efficiency whatever the style produced. Thus it becomes important to exclude setup times and setup changes from a comparison and only compare actual running or productive times. In such a scenario stop levels would be the one main indicator of productivity of that process. The stop levels increase as a new complex product is introduced in the system as seen in table 1 in section 5.1.1.3 of this paper. This increase in stop levels corresponds to the new product and helps in identification of problems and improvement of the process. The changes made to the manufacturing of the new product can be tested by observing the stop levels, which should decrease with improvement in the process thus improving the productivity of the process as well. This does not eliminate the differences of input factors, but it puts them on the same scale. Essentially this provides a somewhat improved comparability, like total factor productivities compared to single factor productivities.

At the same time it needs to be pointed out that the overall productivity of complex product mix scenarios should be expected to be lower than the productivity of commodity production situations. This affects the facility both in cost and comparison as the facility is then compared to other facilities on the basis of cost analysis of the operations without considering the range of products involved. While the lower productivity has a negative effect on cost, the wider product range is usually expected to provide higher revenues in the market.

In terms of addressing specific areas for improvement, productivity measures should be specifically designed to address areas targeted for improvement, for example setup costs or setup times in a complex product mix environment. Such measurements may not be very useful in comparing different plants, especially if they have very different product ranges. However, such comparisons of rather different plants are probably better done by using financial measures and profitability analyses. Another method of comparison as mentioned earlier is using stop levels in which the major indicators would be stops per hour and minutes per stop.

5.2.1 Productivity and Quality

One of the major problems in measuring productivity is that it is not always related to quality. Productivity is taken to be of products of good quality (sellable) and doesn't take into account number of faulty products or waste produced. Any study of productivity should measure output as the number of usable, sellable, acceptable goods or services produced. There should be a mechanism to monitor the defects, faulty output and include them in calculations of non-productivity. It is important to measure the opposite to validate the other part. This measurement will also help relate productivity to quality measurement and quality measurement of outputs would not be a separate process.

In an interview with Mr. JN the concept and relationship of productivity and quality was further discussed. He described a practical approach towards improving efficiency and reducing costs that also results in better quality. The concept of Stop-Levels was used in Company 1. This measurement helps to better understand the operations. An observation of the Stop-Level number shows the efficiency of the operation and in comparison with a standard gives approximate results of how close the operation is to which level of quality. For example, in the weaving operation the number of times a loom stops due to some problem decreases productivity while at the same time increasing the probability of manufacturing faults in the fabric. Stop-Levels give a very good reference to how well the process is running. (Company 1 interview)

6 Case Study 2: Cost Analysis of single pick compared to multiple pick insertion per shed

This case study was conducted to analyze the differences in productivity and the effects on raw material, labor and operations cost with changes in number of pick insertions per shed. It was decided to choose two fabrics with different pick insertions per shed but with similar fabric construction for comparable analysis. The case study was done using interviews at Company 1.

6.1 Fabrics

The following fabrics were chosen:

1. 122 ends per inch, 122 picks per inch, double pick
2. 122 ends per inch, 132 picks per inch, single pick

The fabrics have similar construction and both are sheeting fabrics, so they are suitable for comparison.

6.2 Hypothesis

In this case study the hypothesis is: Switching from single to double pick will increase productivity but decrease the quality of the fabric.

If the above hypothesis is true then the official productivity measures used by the U.S Department of Labor are flawed as they do not differentiate between the pick type of the fabrics. According to the Department of Labor's categorization the two different fabrics with highly contrasting productivities are in the same category thus providing misleading information for analysis.

6.3 Production Analysis

It is important for this case study to note the production parameters that were used as the basis of the calculations. Some of the parameters are:

- Machine speed 625 picks per minute
- Machine efficiency 100% (theoretical efficiency to simplify case study, real efficiencies can be found in Appendix B)

The first fabric with double picks per shed would have the following production results;

1250 pick insertions/min @ 625 ppm

$$\frac{1250 \text{ picks} \times \text{inch}}{\text{Min} \times 122 \text{ picks}} \times \frac{60 \text{ min} \times \text{yards}}{\text{hour} \times 36 \text{ inches}} = 17 \text{ yards per hour}$$

The second fabric with single pick per shed would have the following production results:

625 pick insertions/min @ 625 ppm

$$\frac{625 \text{ picks} \times \text{inch}}{\text{Min} \times 132 \text{ picks}} \times \frac{60 \text{ min} \times \text{yards}}{\text{hour} \times 36 \text{ inches}} = 7.88 \text{ yards per hour}$$

The above production calculations show that with similar constructions the double pick has higher productivity levels as compared to single pick. This is an obvious result of the calculation that will provide the basis for further analysis of productivity measures.

6.4 Analysis of Productivity

The double pick fabric produces twice as much as the single pick fabric with same amount of labor and time involved. The problem area for single pick is that the labor hour per yard is higher than the labor hour per yard for double pick. If the labor is being paid $10/hour in the weave room then for single pick the cost is approximately $1.25/yard, while for the double pick cost is $0.58/yard.

Labor productivities also can be seen to increase when switching from single to double pick per shed. The same labor is giving more output per labor hour input into the system.

6.5 Analysis of Costs

The cost of labor per yard in this example for single pick is $1.25 and it is $0.59 for the double pick fabric. This is a very simple calculation to show how the increase in productivity reduces the cost of labor. The cost of materials should remain the same as both fabrics have similar constructions, so the amount and weight of material used should be similar.

It was also observed during the case study that the number of stop levels is higher for single pick fabrics (15/100,000 yards) than double pick fabrics (10/100,000 yards) but in spite of the 50% difference the number is so low that it is considered negligible in terms of maintenance cost. Long term maintenance cost can be higher as it will take twice as long to produce the same yardage of single pick fabric compared to the double pick fabric.

The efficiencies during the case study are assumed as 100% but this is generally not true at the manufacturing level. The stop levels suggest that single pick fabrics might have slightly lower efficiency than double pick fabrics. It can be suggested that with single pick there is only one yarn being abraded on all sides by the surrounding warp, while with double pick the second filling yarn might provide some protection for both yarns. It can also be argued that the second filling yarn also abrades the first filling yarn and vice versa but with direction of both yarns being same the abrasion might not be as high as with warp yarns going over or under the filling.

Also to produce the same amount of fabric the machine has to run longer for single pick fabric when compared to double pick fabric. The long run times for single pick fabric provide more opportunity for normal breaks during the weaving operation than when running double pick fabrics where total time of production for same amount of fabric may be half the time of single fabric.

6.6 Discussion

The above case study provides a simple and interesting observation of productivity. In this case the labor, machine and material remained same for both the fabrics, yet a huge increase in productivity is observed when switching from single pick to double pick per shed.

This is interesting since no changes were made to the way labor operated. The reverse is true when switching from double to single pick per shed as the labor productivity and the overall productivity of the process will decrease accordingly. This is of concern to the industry if the customer switches from double pick to single pick per shed fabrics. This shift may happen because of customer's perception of difference in quality. The customer here is the retailer/ whole seller and not the customer who is buying the product for his/her household. The difference in quality is minimal as similar raw material is being used. This switch cuts productivity into half and increases the cost of the product. A problem arises if the corresponding selling price does not change proportionally. This puts extra pressure on manufacturing to cut costs to remain competitive with producers around the world.

The switch from double to single pick per shed is based on customer perception of better quality, aesthetics and hand feel. As mentioned earlier the stop levels for both of the fabrics are not very far apart thus the number of defects in both the fabrics are similar hence the quality difference is almost negligible. It was observed during the case study that customers' decision to convert on the basis of quality is arguable because no value is added to the product in terms of raw material quality or machine use (similar machines are used for both products). Also this customer is a retailer or a whole seller and not the end of the chain customer who will be using the product.

It is important that single and multiple pick fabrics are categorized separately when measuring productivity and costs. Considering both fabrics in one category provides misleading and meaningless numbers for analysis.

- Fabrics with different pick insertions per shed should be categorized separately for productivity measures.
- Fabrics with different constructions (plain weave, sateen, etc) should also be categorized separately to useful productivity measures.
- Cost competitiveness of the U.S textile industry decreases when switching from double pick to single pick for negligible quality improvements.

7 Case Study 3: Company 2

7.1 Introduction

This case study deals with productivity and efficiency measures used in an apparel manufacturing organization. Company 2 specializes in manufacturing shirts. The shirts can be manufactured in bulk quantities as well as small customized orders. Company 2 is set up to run small production runs (as low as 12 shirts per order) for majority of its production. The product mix is complex and the style change velocity high.

Company 2 has an advantage that they are closer to the market than any of their competitors around the world so are better equipped to respond to changes in style or design. They also export the shirts to Japan on the basis of a marketing strategy that emphasizes the shirt carrying a 'Made in U.S.A' label.

7.2 Productivity Measures

Company 2 uses a similar method of productivity measurement to the method of Company 1. The basic criterion for measurement at Company 2 is based on the stop times during the processes. This can be viewed as a derivative of efficiency measurement in the reversed.

Company 2 has comparative data available for all the processes in the manufacturing department. This data was compiled using time and motion studies as well as GSD (Garment Sewing Data) technology to find standard times for each process. The loss of time is measured at each process and then compared to the standard data for that process. The measured data has to lie within a certain range (not specified) of the standard data. This range serves as an indicator of productivity of the process.

This method utilizes efficiency calculations and from these calculations productivity is derived to monitor or improve the process if necessary. It can be stated that productivity is observed as the amount of time spent off-standard and the corresponding loss of output in that time period compared to the inputs during that time.

7.3 Factors affecting Productivity

The factors involved in this scenario are again similar to those at Company 1, even though the manufacturing processes and setup of the processes is completely different.

The following factors are affecting the loss of productive time;

- Set up time

This is the time to set up a style for a production run. The sequencing of operations is based on the style of the shirt.

- Wait time

It is the time it takes material to move at the end of one operation to the start of next operation. This is the time the next operator has to wait before the material arrives at his/her station. This time can be affected by re-work of a certain operation as that operation has to be repeated.

- Re-work

A faulty operation performed during the production has to be fixed, hence re-work. This re-work can be done using two different methods. One is to send the faulty piece back to the same station where the fault occurred, second is to send the faulty piece to a specialized fault mending operation.

- Change of operator

The operators at Company 2 have training in performing more than one operation. The operators can switch from one station to another without losing their efficiency but the time spent on setting up for the new operation affects the time lost compared to standards.

7.4 Cost Structure Analysis

The cost structure at Company 2 is very peculiar as they are assessed by comparison with the budgeted cost of productions and not productivity or efficiency numbers. The allocated cost of operations includes all costs of running the plant such as wages, overheads and even medical insurance.

Company 2 has an overhead factor of 2.7 on operator wages or direct labor cost. This extra amount includes overheads such as management salaries and medical insurance for all employees in the plant. The major portion of the overhead cost is caused by medical costs (exact amount not specified). Medical cost becomes a large part of product cost thus reducing Company 2’s competitiveness in the international market. Considering an overhead burden of 270% indicates that productivity gains in manufacturing play a relatively minor part in terms of cost competitiveness. Especially if production levels are decreasing, overhead cost can cause significant problems as they tend to remain fix.

7.5 Discussion

While comparing the case studies of Company 1 and Company 2, it can be observed that even though the plant setups and processes are different similar productivity indicators are being utilized. It was observed while analyzing the case study that at industry level, productivity is measured more or less using the same indicators and similar factors are involved that affect productivity. Company 1 and Company 2 both utilize comparison with standards for analysis of operations and productivity.

The extra charge of overheads and medical costs is a huge amount that raises the cost of a product to a level where it becomes difficult for Company 2 to compete with manufacturers around the world on the basis of price. Company 2 emphasizes their quality levels (only 2% rejects) and throughput times than the cost of their products.

8 Conclusions

The research project showed that productivity data used by the Department of Labor may be misleading when used to analyze competitiveness.

The criterion that is used to measure productivity for a normal manufacturer running commodity styles over a long run, i.e., large batch sizes, cannot be applied to a complex product mix situation. At the company level productivity measures are:

- not well suited for competitive comparisons
- well suited for process optimization
- well suited for capacity planning

The research provides significant arguments that overall productivity of complex product mix scenarios should be expected to be lower than the productivity of commodity production situations. This complex product mix scenario affects facilities both in cost and comparison as since they essentially serve different markets.

The research shows that the current productivity measures should not be applied to a complex product mix. While at the same time productivities for commodity products can not be used for comparison using the current Department of Labor measures as well as reporting methods.

The above argument is made stronger by the fact that different fabrics are compared in same categories by the Department of Labor. Fabric with different specifications such as number of picks inserted per shed should be categorized separately to measure productivity and costs. Information of both fabrics in one category would provide misleading and meaningless numbers for analysis as observed earlier in the paper during case study analysis.

It was also identified in the case study that there are significant corporate and plant overhead costs (e.g. medical) that have a great impact on the cost structure. However, analyzing these costs was not within the scope of this research.

In all cases, productivity measures by their very nature of using specific physical output units serve as a measure of very specific operations. In that respect they provide an opportunity for analysis as well as feedback. In an era when production capacity was the bottleneck of an organization's performance, overall performance could be improved by focusing attention on the overall production efficiency or manufacturing productivity as the key indicator of competitive ability and strength. However, today manufacturing is not necessarily the bottleneck of a corporation, and the efficiency of other business aspects as well as market forces play a much greater role in defining the competitive strength of a corporation.

Of course productivity measures remain an important tool in helping define and improve manufacturing, and they are also applied to help measure and improve non-production labor utilization, or knowledge worker productivity (P. Drucker, 1999). And in terms of manufacturing productivity the focus may have to shift from traditional operator productivity towards measures that consider product mix complexity, which in turn is driven by market forces more than production variables.

9 Recommendations

- Total factor productivities (output/total cost) or the inverse 'cost per unit output' are better suited than labor productivities in evaluating the competitive situation of manufacturing.

- As overhead costs make a large portion of total cost than direct labor cost, their investigation becomes more important in determining competitive positions.

- At the firm level it is recommended to modify the economies of scale setup to specialized models for shorter product runs and increased product complexity. This will also be beneficial in light of the increase in style change velocity at plant level.

- Operation focused costing (activity based) is recommended at plant level where the operators are involved in multitasking. This will provide a better estimate of the labor cost for a particular product.

- Textile companies involved with manufacturing should invest towards technology to make the manufacturing more flexible and following customer demand. One suggestion is designing different patterns utilizing the same warp in order to avoid time consuming warp changes. This will require use of standard warp threads that can be utilized for multiple designs. This can be done by utilizing computerized Jacquard machines. Filling pattern changes can be done automatically via computer controlled equipment, resulting in less or no downtime for this type pattern change (i.e., productivity stays high in spite of complex product mix). This will provide the manufacturing company with flexibility of design changes while keeping productivity high and they can charge extra for these designs as they can be customized and delivered in small quantities with short lead times. The cost of operations should not be very high as the process should be highly automated, but the cost of designing patterns that can compliment the manufacturing setup would be high. The number of designers required for such a manufacturing setup will be considerably higher than a normal manufacturing setup.

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11 Appendices

11.1Appendix A

11.1.1 Interview of Company 1

Q1) How important is productivity measurement and does it help in being more competitive?

JN: It is a key measurement but it is measured using stop levels in our plant at all levels.

It helps us in comparing our production operations at different levels.

Q2) How do you measure productivity of each operation?

a) Do you measure total productivity, and if so, how?

JN: As I told you earlier, we use stop levels to monitor the production but we also compare efficiencies of each process with standard efficiencies. This provides information on productivity levels of each operation. We also use defects per standard yardage to monitor the situation at each operation. Each operation is measured separately and we do not have a specific measure to sum all operations.

Q3) How do you measure;

- Costs

JN: The costs are measured using stop level data. The stop times are translated into costs related to time lost because of the stoppages.

Q4) How do you measure Output for each operation?

JN: We use the usual way of observing the production numbers of each operation, nothing special.

Q5) How do you account for waste in each operation?

JN: We have a weekly production statement that accounts for waste at each process that is calculated at each step manually.

Q6) How do you incorporate that waste in efficiency calculations?

JN: The yield of each process already incorporates waste in the calculations.

Q7) What do you consider the most important cost factor in each of the manufacturing operations?

JN: The raw material costs are right at the top but one other cost that has been increasing our overall cost is the medical and healthcare cost. The medical costs are becoming a major part of labor cost.

Q8) How do you compare with your competitors in;

- Cost
- Quality
- Productivity

JN: We use data from our vendors when it is available to compare our production facilities. We outsource some of our production domestically due to lack of capacity to vendors like yarn manufacturers. It is easier to get information from these vendors than competitors.

Q9) Do you benchmark any organization for the above?

JN: Yes! We have mutual benefit agreements with our vendors through which both parties can take out and implement the best policies.

Q10) Do you see a link between Productivity and Quality?

JN: Of course, with lower stop levels and better efficiencies the quality automatically improves. The less the production has to stop more consistent is the quality of the product in production.

Q11) What are the changes that you would like to make in the process or measurement of process to make it better?

JN: We would like to minimize style change velocity as it hurts our productivity numbers. We have to change our styles more often than we used to a couple of years ago which accounts for more downtime hence loss of production time.

11.1.2 Interview of Company 2

Q1) How important is productivity measurement and does it help in being more competitive?

Bill: We have stopped using productivity measurement for competitive purposes because we are working on a different structure. We are not competing with any other manufacturer because it is not possible to compete on the basis of price but our advantage is close proximity to the customer. We use productivity indicators to help us out in improving our processes.

Q2) How do you measure efficiency and productivity of each operation?

a) Do you measure total productivity, and if so, how?

Bill: Our method is inverse of productivity measurement. We compare loss of time to observe our efficiencies. We compare operations data with standard sewing data that helps us analyze our facility.

Q3) How do you measure;

- Costs

Bill: We have a fixed expense budget and we are allowed a certain percentage to go over the standard budget. Standard budget is calculated using ideal conditions and we are allowed to go over because the top management understands that we can not match the prices of outsourced products. Our costs increase because our orders are low quantity sometimes even less than a dozen per style.

Q4) How do you account for waste in each operation?

Bill: There are a couple of ways that we observe waste in our operations. We observe the total material input in the process and the total amount out of the process, which is a usual way of accounting for waste. We also observe data from each operation and calculate waste by comparison of time lost during operations.

Q5) How do you incorporate that waste in efficiency calculations?

Bill: The waste as I told you earlier is incorporated in the calculations by observing the time lost during operations.

Q6) What do you consider the most important cost factor in each of the manufacturing operations?

Bill: Our labor cost is higher than our competitors plus very high medical costs are a big part of the cost structure.

Q7) How do you compare with your competitors in;

- Cost

- Quality
- Productivity

Bill: It is not possible for us to compete with our competitors in cost. We can easily compete in quality as we do a lot of custom production runs that are high quality products. Our competitors are also using similar setups so our productivity levels are similar as well. We got this information because we have a mutual partnership with a few vendors off-shore.

Q8) Do you benchmark any organization for the above?

Bill: We have a pretty good infrastructure and we compare data with Garment Sewing Data (GSD) system. So in a way, we benchmark the standards of the system to improve our operations.

Q9) Do you see a link between Productivity and Quality?

Bill: We look at productivity as time spent off-standard (GSD). It has been quite apparent to us that the less time we spend off-standard better quality of products are seen getting off the production line.

Q10) What are the changes that you would like to make in the process or measurement of process to make it better?

Bill: I would personally like to separate the medical costs from the cost of the product so we can compete on the basis of our operations efficiency because right now with all the overheads and medical costs, it is impossible for us to compete.

11.2 Appendix B

REPORT NO. 87080-A
REPORT DATE 07/25/05
TIME 14:36

SPRINGS INDUSTRIES, INC.
WEEKLY PRODUCTION REPORT
BY PROCESS & BULLETIN NO.

PAGE 4
AS OF 07/23/0
FINAL COPY

PLANT: 23 KATHERINE   DEPT: 20 SLASHING   ROOM: 001 ONE

OPERATION	BUL NO.	MACHINE MODEL	DEL PER FRM	SPEED	NBR OF MACHS	PIECES PRODUCED	ACTUAL PRODUCTION	HOURS	100% PRODUCTION	STANDARD PRODUCTION	STD EFF	ACT EFF
1104 37 50/50 OES	104	IG	1	110.00000	.07	33119.00	33119.00	168.0	79200.00	36685.44	46.32	41.8
1121 41 40/60 OES	121	IG	1	110.00000	.50	165228.00	165228.00	168.0	554400.00	211891.68	38.22	29.8
1125 40/60 OES	125	IG	1	110.00000	.17	81850.00	81850.00	168.0	184800.00	81663.12	44.19	44.2
1245 41 4060 OES	245	I G	1	110.00000	.14	81220.00	81220.00	168.0	158400.00	77600.16	48.99	51.2
1249 37.5 5050 OES	249	I G	1	90.00000	.09	53480.00	53480.00	168.0	82350.00	37724.53	45.81	64.9
1329 41 4060 OES	329	I G	1	110.00000	.14	80684.00	80684.00	168.0	158400.00	71818.56	45.34	50.9
1331 41 40/60 OES	331	IG	1	110.00000	.74	328904.00	328904.00	168.0	819499.99	369266.69	45.06	40.1
1332 41 40/60 OES	332	IG	1	90.00000	.16	82165.00	82165.00	168.0	148500.00	72913.50	49.10	55.3
1349 37.5 MJS	349	I G	1	110.00000	.14	62300.00	62300.00	168.0	158400.00	76380.48	48.22	39.3
1403 40/60 OES	403	IG	1	110.00000	.19	82467.00	82467.00	168.0	211200.00	93329.28	44.19	39.0
1813 41 4060 OES	813	I G	1	110.00000	.07	20725.00	20725.00	168.0	79200.00	32598.72	41.16	26.1
1943 37.5 OES	943	I G	1	110.00000	.11	62235.00	62235.00	168.0	118249.99	56795.47	48.03	52.6
1955 41 5050 MJS	955	IG	1	110.00000	.03	17896.00	17896.00	168.0	35749.99	17631.89	49.32	50.0
1959 41 5050 MJS	959	IG	1	110.00000	.19	83530.00	83530.00	168.0	216150.00	105913.50	49.00	38.6
1973 40/60 OES	973	IG	1	110.00000	.13	41114.00	41114.00	168.0	145200.00	63394.32	43.66	28.3
	CC	01 TOTAL		*********	2.89	1276917.00	1276917.00	168.0	3149699.99	1405607.36	44.63	40.5
	ROOM	001 TOTAL		*********	2.89	1276917.00	1276917.00	168.0	3149699.99	1405607.36	44.63	40.5

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14:36

WEEKLY PRODUCTION REPORT
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PLANT: 23 DEPT: 20 ROOM: 002

OPERATION	BUL NO.	MACHINE MODEL	DEL PER FRM	SPEED	NBR OF MACHS	PIECES PRODUCED	ACTUAL PRODUCTION	HOURS	100% PRODUCTION	STANDARD PRODUCTION	STD EFF	ACT EFF
1404 COTTON SATEEN	140	I G	1	80.00000	.04	4290.00	4290.00	165.0	28800.00	6727.68	23.36	14.9
1301 37.5 5050 MJS	301	I G	1	110.00000	.13	62223.00	62223.00	165.0	141900.00	64011.09	45.11	43.8
1328 40/60 MVS	328	IG	1	80.00000	.26	96681.00	96681.00	165.0	202399.99	101503.59	50.15	47.7
1329 41 4060 OES	329	I G	1	110.00000	.14	81434.00	81434.00	165.0	155100.00	70322.34	45.34	52.5
1332 41 40/60 OES	332	IG	1	90.00000	.19	81920.00	81920.00	165.0	171899.99	84402.89	49.10	47.6
1401 35.0 MVS	401	IG	1	70.00000	.22	28481.00	28481.00	165.0	151200.00	35320.32	23.36	18.8
CC 01 TOTAL				*********	.98	355029.00	355029.00	165.0	851299.99	362287.92	42.56	41.7
ROOM 002 TOTAL				*********	.98	355029.00	355029.00	165.0	851299.99	362287.92	42.56	41.7
DEPARTMENT 20 TOTAL				*********	3.86	1631946.00	1631946.00	167.2	4000999.99	1767895.29	44.19	40.7
CC 01 GRAND TOTAL				*********	3.86	1631946.00	1631946.00	167.2	4000999.99	1767895.29	44.19	40.7

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PLANT: 23 KATHERINE DEPT: 25 WEAVING ONE ROOM: 001 ONE

OPERATION	BUL NO.	MACH INE MODEL	DEL PER FRM	SPEED	NBR OF MACHS	PIECES PRODUCED	ACTUAL PRODUCTION	HOURS	100% PRODUCTION	STANDARD PRODUCTION	STD EFF	ACT EFF
WEAVE P1104	104	PAT	1	563.00000	4.29	217.75	14066.53	168.0	243.21	223.11	91.74	89.53
WEAVE Z1328-250	118	ZAX	1	636.00000	1.79	100.99	5202.67	168.0	114.48	106.45	92.99	88.22
WEAVE Z1328-280	119	ZAX	1	637.00000	1.00	51.66	2661.35	168.0	64.20	59.08	92.02	80.46
WEAVE 1125	125	PIC	1	563.00000	7.00	346.66	18168.76	168.0	397.25	347.59	87.50	87.26
WEAVE 1132F	133	PAT	1	563.00000	22.57	1150.38	50924.33	168.0	1280.93	1135.37	88.64	89.81
WEAVE 1132F BWF	134	PAT	1	563.00000	1.43	71.34	3158.03	168.0	81.07	70.24	86.64	88.00
WEAVE Z1404 ZAX	140	ZAX	1	500.00000	14.29	461.50	15081.70	168.0	720.00	534.23	74.20	64.10
WEAVE 1968	168	OMNI	1	625.00000	2.00	103.90	4826.27	168.0	126.00	112.40	89.21	82.46
WEAVE Z 1217ZBWF	172	ZAX	1	579.00000	1.00	50.29	2688.50	168.0	58.36	49.73	85.22	86.17
WEAVE Z1332 Z	191	ZAX	1	579.00000	12.00	622.71	32079.96	168.0	700.35	609.14	86.98	88.91
WEAVE 1193 BWF MVS W	194	PIC	1	467.00000	1.00	36.54	1882.42	168.0	47.07	39.54	84.00	77.62
WEAVE 1959 F	195	PAT	1	563.00000	13.00	636.18	28162.03	168.0	737.75	647.44	87.76	86.21
WEAVE 1193 BWF OES W	196	PIC	1	467.00000	2.00	83.17	4284.64	168.0	94.14	79.56	84.51	88.34
WEAVE 250-1211 ZAX	211	ZAX	1	670.00000	15.00	866.33	40241.98	168.0	1013.04	894.97	88.35	85.52
WEAVE Z1214-280 ZAX	214	ZAX	2	636.00000	14.00	732.54	34027.28	168.0	897.52	797.42	88.85	81.62
WEAVE Z1215-280	215	ZAX	2	637.00000	5.00	269.57	11068.81	168.0	321.04	283.68	88.36	83.97
WEAVE Z 1217Z	217	ZAX	1	579.00000	6.00	315.04	16842.03	168.0	350.17	321.98	91.95	89.97
WEAVE Z 1121Z	222	ZAX	1	571.00000	5.00	246.88	11467.84	168.0	287.78	243.90	84.75	85.79
WEAVE 1224	224	PIC	1	563.00000	4.71	222.14	9121.29	168.0	267.53	227.94	85.20	83.01
WEAVE 1224 MVS WARP	225	PIC	1	563.00000	1.29	58.49	2401.65	168.0	72.96	64.22	88.03	80.16
WEAVE Z1245	245	ZAX	1	636.00000	12.00	660.08	42640.82	168.0	769.30	703.32	91.42	85.80
WEAVE 1328 MVS WARP	283	PIC	1	563.00000	5.00	245.93	12669.50	168.0	283.75	238.11	83.92	86.67
WEAVE Z1328-250 MVS	284	ZAX	1	636.00000	3.00	157.89	8133.97	168.0	192.32	172.09	89.48	82.09

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PLANT: 23 KATHERINE DEPT: 25 WEAVING ONE ROOM: 001 ONE

OPERATION	BUL NO.	MACH INE MODEL	DEL PER FRM	SPEED	NBR OF MACHS	PIECES PRODUCED	ACTUAL PRODUCTION	HOURS	100% PRODUCTION	STANDARD PRODUCTION	STD EFF	ACT EFF
WEAVE Z1328-280 MVS	285	ZAX	1	637.00000	12.21	689.92	35542.40	168.0	784.27	693.27	88.40	87.9
WEAVE Z 1813Z	318	ZAX	1	579.00000	10.00	497.44	26593.14	168.0	583.63	517.77	88.72	85.2
WEAVE 1328	328	PIC	1	563.00000	2.00	98.33	5065.63	168.0	113.50	100.81	88.82	86.6
WEAVE 1331	331	PIC	1	467.00000	14.00	598.71	30843.56	168.0	659.03	596.59	90.53	90.8
WEAVE Z 1331Z	332	ZAX	1	579.00000	15.00	789.39	40666.76	168.0	875.44	788.90	90.11	90.1
WEAVE 1934 DP	334	PIC	1	563.00000	6.00	313.29	16419.81	168.0	340.50	304.03	89.29	92.0
WEAVE Z1346 ZAX	346	ZAX	1	500.00000	16.71	546.38	17855.55	168.0	842.40	660.18	78.37	64.8
WEAVE Z1348 ZAX	348	ZAX	1	636.00000	6.00	229.71	10670.28	168.0	384.65	314.68	81.81	59.7
WEAVE 1943 MJS WARP	349	PIC	1	563.00000	.36	15.06	972.86	168.0	20.26	18.51	91.36	74.3
WEAVE Z1973 ZAX	373	ZAX	1	636.00000	12.00	635.79	29533.14	168.0	769.30	656.44	85.33	82.6
WEAVE P1943-DP	378	PIC	1	563.00000	4.64	248.13	16029.07	168.0	263.48	238.73	90.61	94.1
WEAVE P1943-DP BWF	392	PIC	1	563.00000	2.00	103.95	6715.11	168.0	113.50	101.22	89.19	91.5
WEAVE 1405	405	PIC	1	467.00000	22.29	938.49	60625.96	168.0	1049.06	942.08	89.80	89.4
WEAVE 1405-280	406	PIC	1	563.00000	.71	35.25	2277.13	168.0	40.53	37.22	91.83	86.9
WEAVE 1405-MVS	407	PIC	1	467.00000	.71	26.89	1737.08	168.0	33.62	30.00	89.24	79.9
WEAVE P1268-DP	417	PAT	1	563.00000	1.00	51.41	3321.05	168.0	56.75	51.08	90.01	90.5
	CC	01 TOTAL		*********	280.00	13526.10	676671.05	168.0	16050.30	14013.22	87.31	84.2
	ROOM	001 TOTAL		*********	280.00	13526.10	676671.05	168.0	16050.30	14013.22	87.31	84.2
	DEPARTMENT	25 TOTAL		*********	280.00	13526.10	676671.05	168.0	16050.30	14013.22	87.31	84.2

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PLANT: 23 KATHERINE   DEPT: 26 WEAVING TWO   ROOM: 001 ONE

Complex

OPERATION	BUL NO.	MACHINE MODEL	DEL PER FRM	SPEED	NBR OF MACHS	PIECES PRODUCED	ACTUAL PRODUCTION	HOURS	100% PRODUCTION	STANDARD PRODUCTION	STD EFF	ACT EFF
WEAVE 1401 ORGANIC	401	OMNI	1	525.00000	5.14	150.28	4911.11	168.0	272.16	193.89	71.24	55.2
WEAVE 1402 SATEEN	402	OMNI	1	525.00000	7.00	237.84	7772.54	168.0	370.44	269.97	72.88	64.2
WEAVE 1403	403	OMNI	1	625.00000	.29	14.63	945.09	168.0	18.00	16.06	89.24	81.2
WEAVE 1226	622	OMNI	1	625.00000	11.00	598.42	24571.72	168.0	693.00	609.09	87.89	86.3
WEAVE 1346 SATEEN	643	OMNI	1	525.00000	9.00	290.77	9502.28	168.0	476.28	337.28	70.82	61.0
WEAVE 1337	733	OMNI	1	625.00000	1.86	34.23	1033.51	168.0	117.00	83.65	71.50	29.2
WEAVE 1347	743	OMNI	1	525.00000	16.29	681.22	31020.94	168.0	861.84	656.29	76.15	79.0
WEAVE 1347 BWF	744	OMNI	1	525.00000	2.00	85.61	3898.45	168.0	105.84	80.78	76.32	80.8
WEAVE 1197	791	OMNI	1	625.00000	6.00	340.89	22021.49	168.0	378.00	339.43	89.80	90.1
WEAVE 1329	888	OMNI	1	625.00000	15.00	853.44	43966.41	168.0	945.00	856.81	90.67	90.3
WEAVE 1331F	890	OMNI	1	625.00000	36.43	2061.96	106225.37	168.0	2295.00	2066.84	90.06	89.8
WEAVE 1301	901	OMNI	1	625.00000	10.00	578.25	37354.95	168.0	630.00	570.72	90.59	91.7
WEAVE 1121	921	OMNI	1	625.00000	48.14	2553.10	118594.30	168.0	3033.00	2631.25	86.75	84.1
WEAVE 1249	942	OMNI	1	625.00000	10.71	634.02	40957.69	168.0	675.00	613.43	90.88	93.9
WEAVE 1968	968	OMNI	1	625.00000	21.14	1155.13	53657.05	168.0	1332.00	1168.90	87.76	86.7
WEAVE 1189 BWF	982	OMNI	1	625.00000	4.00	228.91	11792.68	168.0	252.00	224.58	89.12	90.8
WEAVE 1332	991	OMNI	1	625.00000	26.00	1451.79	74791.42	168.0	1638.00	1454.05	88.77	88.6
CC 01 TOTAL				*********	230.00	11950.49	593017.08	168.0	14092.56	12173.10	86.38	84.8
ROOM 001 TOTAL				*********	230.00	11950.49	593017.08	168.0	14092.56	12173.10	86.38	84.8
DEPARTMENT 26 TOTAL				*********	230.00	11950.49	593017.08	168.0	14092.56	12173.10	86.38	84.8

1269.7

11.3Appendix C

Different styles with complex

A-MILL Zax 7/27/2006

STYLE	BULL. NO.	PPM	2006 BUDGET PTS/LM	CURR PTS/LM	PROP PTS/LM	INSTL PTS/LM	2006 BUDGET	2006 BUDGET POINTS VARIANCE	PROP	CURR	# Looms	STYLE	POINTS VARIANCE	JSS EFF	Earning loss due to stop level		
1211z	211	670	6.212	8.713	10.843	8.713	93.18	-69.47	162.65	130.70	15	1211z	32.0	86.46%	-$1,336	-$848	T-1F 250 Blend DP 40/60
1214z-280oes	214	636	7.864	7.593	7.734	7.593	110.10	1.82	108.28	106.30	14	1214z-280oes	2.0	88.71%	$35		
1121z	222	571	7.178	11.072	13.818	11.072	35.89	-31.69	67.58	55.36	5	1121z	12.2	83.40%	-$610		
1973z	373	636	11.680	9.941	11.708	9.941	138.96	-1.54	140.50	119.29	12	1973z	21.2	84.11%	-$30		
1348z	348	636	27.962	19.380	18.652	19.380	167.77	55.86	111.91	116.28	6	1348z	-4.4	80.03%	$1,075		
1968/omni	168	625	8.319	6.591	7.851	6.591	16.64	0.94	15.70	13.18	2	1968/omni	2.5	87.93%	$18		
1328z 280	119	637	8.364	3.376	7.787	3.376	8.36	0.58	7.79	3.38	1	1328z 280	4.4	89.38%	$11	$2,318	T-3J Luxury
1328z 280/MVS	285	637	12.400	8.039	7.051	8.039	161.20	69.54	91.66	104.51	13	1328z 280/MVS	-12.8	90.08%	$1,338		
1328z 250	118	636	8.398	3.876	8.509	3.876	8.40	-0.11	8.51	3.88	1	1328z 250	4.6	88.73%	-$2		
1328z 250mvs	284	636	12.335	8.285	8.059	8.285	37.01	12.83	24.18	24.86	3	1328z 250mvs	-0.7	89.22%	$247		
1331z	332	579	8.262	5.913	6.066	5.913	123.93	32.96	90.98	88.70	15	1331z	2.3	90.12%	$634		
1332z	191	579	10.035	10.553	9.641	10.553	120.42	4.73	115.69	126.64	12	1332z	-10.9	87.79%	$91		
1245z	245	670	8.467	5.925	8.143	5.925	101.48	3.77	97.72	71.10	12	1245z	26.6	88.83%	$72	$72	T-3K 180 MC Blend DP 40/60
1346z	346	500	20.433	21.874	22.588	21.874	265.63	-28.02	293.64	284.36	13	1346z	9.3	77.95%	-$539	-$539	T -97 230 CT. Cotton Sateen
1404z	140	500	29.991	29.375	26.716	29.375	539.84	76.95	462.89	528.75	18	1404z	-65.9	75.40%	$1,480	$1,480	
1215z	215	636	7.517	8.900	8.697	8.909	37.59	-5.90	43.49	44.55	5	1215z	-1.1	88.40%	-$113	-$113	T-3F Luxury
1813z	318	571	10.963	7.316	6.333	7.316	109.53	46.20	63.33	73.15	10	1813z	-9.8	89.84%	$889	$872	T-3A 220 Supercale DP 40/60
1217z	217	571	6.267	4.768	5.811	4.768	37.60	2.74	34.87	28.61	6	1217z	6.3	90.97%	$53		
1217BWFz	172	571	6.267	10.634	9.848	10.634	6.27	-3.58	9.85	10.63	1	1217BWFz	-0.8	87.32%	-$69		
			TOTAL ZAX POINTS				2120	169	1951	1934	164	TOTAL POINT VARIANCE	17		$3,243	$3,243	
			ZAX POINT VARIANCE							99.1							

	2006 BUDGET	2006 BUDGET POINTS VARIANCE	PROP	INSTL						
TOTAL A MILL POINTS	2999	143	2856	2854	280	TOTAL POINT VARIANCE	2	$2,764	$2,764
A MILL POINT VARIANCE				99.9					

Given on the basis of shop levels.

B-MILL 7/27/2005

STYLE	BULL. NO.	PPM	2005 BUDGET PTS/LM	CURR PTS/LM	PROP PTS/LM	INSTL	2005 BUDGET	2005 BUDGET POINTS VARIANCE	PROP	CURR	# Looms		POINTS VARIANCE	JSS			
250-1121	921	625	9.093	9.685	10.108	9.685	445.56	-49.74	495.29	473.59	49	250-1121	21.7	86.31%	-$957	-$1,352	T-1F 250 Blend OP 40/60
250-1968	968	625	8.319	8.637	9.297	8.637	174.70	-20.54	195.24	181.38	21	250-1968	13.9	87.01%	-$395		
L1226	622	625	7.803	8.572	8.867	8.572	85.83	-11.70	97.54	94.29	11	L1226	3.2	87.24%	-$225	-$226	T-3f Luxury
L1329	888	625	9.491	6.084	5.742	6.054	142.37	56.24	86.13	90.81	15	L1329	-4.7	90.79%	$1,082	$4,057	T-3J Luxury
B1403	403	625	6.889	8.108	7.976	8.108	13.78	-2.17	15.95	16.22	2	B1403	-0.3	88.33%	-$42		
L1331-F-K	890	625	9.491	6.402	6.367	6.402	322.69	106.56	216.14	217.67	34	L1331-F/K	-1.5	89.95%	$2,050		
L1189BWF	982	625	7.465	5.178	5.702	5.178	29.86	7.05	22.81	20.71	4	L1189BWF	2.1	90.02%	$136		
L1332	991	625	8.913	7.390	7.250	7.390	231.74	43.24	188.50	192.14	26	L1332	-3.6	88.00%	$832		
1301	901	625	8.785	5.083	5.226	5.083	67.85	15.59	52.26	50.83	10	1301	1.4	90.68%	$300	$300	T -79 Percale Park'd warp
1249	942	625	5.809	5.437	4.539	5.437	52.28	11.43	40.85	48.93	9	1249	-8.1	91.21%	$220	$220	
1197	791	625	10.816	4.847	5.833	4.847	64.89	29.29	35.00	29.08	6	1197	6.5	89.81%	$563	$553	
1346	643	525	19.470	32.700	31.194	32.700	175.23	-105.52	280.75	294.30	9	1346	-13.6	72.78%	-$2,030	-$2,030	T -97 230 CT. Cotton Sateen
1401	401	525	23.824	31.790	28.866	31.790	190.59	-40.34	230.93	254.32	8	1401	-23.4	73.61%	-$776	-$776	T -97 230 CT. Cotton Sateen
1402	402	525	24.138	27.064	26.260	27.064	168.97	-14.85	183.82	189.45	7	1402	-5.6	75.43%	-$286	-$286	
L1347	743	525	23.771	24.538	21.099	24.538	380.34	42.75	337.58	392.61	16	L1347	-55.0	78.30%	$822	$822	
L1347BWF	744	525	18.538	21.343	19.150	21.343	37.08	-1.22	38.30	42.69	2	L1347BWF	-4.4	78.71%	-$24	-$24	
1337	733	625	18.538	34.455	40.947	34.455	18.54	-22.41	40.95	34.46	1	1337	6.5	88.09%	-$421		

	2005BUDGET	POINTS VARIANCE	PROP	INSTL					
TOTAL B MILL POINTS	2602.3	-43.7	2558.6	2023	230	TOTAL POINT VARIANCE	-96 - 45 (-29)	$850	$850
B MILL POINT VARIANCE				102.5					$0

	2005BUDGET	POINTS VARIANCE	PROP	INSTL					
TOTAL PLANT POINTS	5601.0	186.8	5414.4	5477.0	510.0	TOTAL POINT VARIANCE	-62.6	$3,014	$3,014

Complex product

Complex product - low effic.

7/25/2005
7/27/2005 8th Shift

FOR PROPOSED EFFECTIVE DATE:

A-MILL STYLE	Picanol BULL. NO.	PPM	2005 BUDGET PTS/LM	POINTS PER LOOM CURR PTS/LM	PROP PTS/LM	INSTL PTS/LM	TOTAL POINTS 2005 BUDGET	2005 BUDGET POINTS VARIANCE	PROP	CURR	# Looms	STYLE	POINTS VARIANCE	JBS EFF	Earning loss due to stop level		
P1104	104	563	6.409	4.095	4.012	4.095	25.64	9.59	16.05	16.38	4	P1104	-0.3	92.05%	$184	$71	T-79 Percale Park'd warp
280-1405	406	563	6.882	8.325	10.736	8.325	6.88	-3.85	10.74	8.33	1	280-1405	2.4	87.62%	-$74		
P1943dp	378	563	5.342	4.646	4.502	4.646	16.03	2.52	13.51	13.94	3	P1943dp	-0.4	91.50%	$48		
P1943mjs	340	563	5.342	4.646	8.176	4.646	10.68	-5.67	16.35	9.29	2	P1943mjs	7.1	87.62%	-$109		
P1268	417	561	5.525	6.354	3.950	6.354	5.53	1.58	3.95	6.35	1	P1268	-2.4	92.13%	$30		
P1943BWF	392	563	6.830	6.731	7.063	6.731	13.66	-0.47	14.13	13.46	2	P1943BWF	0.7	88.40%	-$9		
1934	334	563	5.683	6.559	5.184	6.559	34.10	2.99	31.10	39.35	6	1934	-8.3	91.10%	$58	-$48	T-3A 220 Supercale DP 40/60
1125	125	563	6.882	8.325	7.667	8.325	48.17	-5.50	53.67	58.28	7	1125	-4.6	88.22%	-$106		
1132-F-bwf	134	563	9.614	10.515	9.204	10.515	19.23	0.82	18.41	21.03	2	1132-F-bwf	-2.6	87.81%	$15		
1132-F	133	563	8.835	7.720	7.712	7.720	194.37	24.71	169.66	169.84	22	1132-F	-0.2	89.13%	$464	$568	T-88 Percale
P1959-F	195	563	8.588	8.412	8.170	8.412	111.64	5.43	106.21	109.36	13	P1959-F	-3.1	88.30%	$105		
L1224mvs	225	563	6.684	10.980	11.433	10.980	6.68	-4.75	11.43	10.98	1	L1224mvs	0.5	85.53%	-$89	-$806	T-3F Luxury
L1224	224	563	6.684	10.509	14.326	10.509	33.42	-38.21	71.63	52.55	5	L1224	19.1 F	83.10%	-$717		
L1328	328	563	6.844	7.166	8.226	7.166	13.69	-2.76	16.45	14.33	2	L1328	2.1	88.27%	-$63	-$279	T-3J Luxury
L1328MVS/W	283	563	10.646	14.059	14.023	14.059	53.23	-16.89	70.12	70.30	5	L1328MVS/W	-0.2	83.80%	-$317		
L1329	329	467	6.889	6.264	11.349	6.264	0.00	0.00	0.00	0.00	0	L1329	0.0	85.62%	$0		
L1405	405	467	7.276	8.108	6.945	8.108	160.07	7.28	152.79	178.38	22	L1405	25.6	91.19%	$137		
L1405mvs	407	467	7.276	8.108	11.655	8.108	7.28	-4.38	11.66	8.11	1	L1405mvs	3.5	87.36%	-$82		
L1193BWF-mvs	194	467	11.524	16.418	14.075	16.418	11.52	-2.55	14.08	16.42	1	L1193BWF-mvs	-2.3	83.45%	-$48		
L1193BWF-oes	196	467	11.524	9.750	8.886	9.750	23.05	5.28	17.77	19.50	2	L1193BWF-oes	-1.7	87.70%	$99		
L1331	331	467	6.006	5.943	6.065	5.943	84.11	-0.80	84.91	83.20	14	L1331	1.7	90.22%	-$15		
			TOTAL PICANOL POINTS				879	-26	905	919	116	TOTAL POINT VARIANCE	-15		-$479	-$479	

PICANOL POINT VARIANCE

11.4Appendix D

KATHERINE PLANT DAILY PREPARATION EFFICIENCY REPORT

W/E 07/23/2005 **WEEKLY**

WARPING

		SUNDAY		MONDAY		TUESDAY		WEDNESDAY		THURSDAY		FRIDAY		SATURDAY		
		A	B	C	D	C	D	A	B	A	B	C	D	C	D	Total
Job 1	Act Eff	57.15	64.72	60.38	69.00	57.42	56.31	53.03	51.76	56.96	57.47	52.90	65.23	59.28	69.65	59.49
	Std Eff	51.13	51.13	51.13	51.60	51.51	51.13	51.13	51.13	50.17	48.85	51.13	51.13	51.13	51.13	50.95
Job 2	Act Eff	55.22	57.50	45.89	47.48	55.66	54.62	50.69	57.18	49.92	51.10	41.17	45.73	45.18	48.56	50.16
	Std Eff	52.30	51.44	51.13	52.19	51.13	51.10	51.13	51.13	53.53	51.13	51.51	50.95	51.13	51.13	51.48
Job 3	Act Eff	45.78	45.83	52.09	38.87	59.28	55.95	54.62	51.49	45.07	46.49	38.76	55.52	51.14	47.42	48.55
	Std Eff	41.97	37.12	46.25	35.36	41.46	47.15	41.65	42.41	48.11	45.47	45.47	43.45	42.13	43.61	43.19
Job 4	Act Eff					48.17	46.25	62.08		58.42	40.54	55.40				46.64
	Std Eff					47.43	54.21	50.61		51.08	50.61	48.52				50.52
Dept	Act Eff	52.77	55.95	52.82	54.41	54.30	50.82	53.40	52.96	51.43	50.54	45.05	55.23	51.88	55.36	52.53
	Std Eff	48.53	46.49	49.68	48.51	49.41	51.28	48.49	47.66	50.54	48.74	49.34	48.50	48.18	48.72	48.97
WTD	Act Eff	52.77	54.42	53.90	54.01	54.07	53.46	53.45	53.41	53.16	52.86	52.10	52.36	52.32	52.53	
	Std Eff	48.53	47.47	48.20	48.27	48.52	49.04	48.96	48.84	49.05	49.02	49.05	49.00	48.94	48.97	

Note: Budgeted Warper Speed is 750 ypm.

Impact of 41's & 37's MJS for OES substitution. * PLANT H – COT PKGS

SLASHING

		SUNDAY		MONDAY		TUESDAY		WEDNESDAY		THURSDAY		FRIDAY		SATURDAY		
		A	B	C	D	C	D	A	B	A	B	C	D	C	D	Total
Job 1	Act Eff	35.46	69.92	65.26	9.17	16.61	29.57	10.33	60.07	57.36	25.13	53.20	54.17	31.76	55.56	41.70
	Std Eff	49.61	49.10	49.10	~~38.99~~	23.36	23.36	23.36	50.15	50.15	50.15	45.34	45.34	45.16	45.11	42.56
Job 2	Act Eff	69.92	23.73	65.41	27.82	53.03	51.39	33.72	74.14	37.19	78.91	11.27	22.78	53.79	26.07	44.08
	Std Eff	45.81	48.26	49.00	49.00	45.06	45.06	46.40	48.03	49.05	49.10	42.76	45.06	45.06	45.06	46.65
Job 3	Act Eff	28.91	60.01	37.55	41.82		46.58	51.12	20.26	63.60	26.90	50.51	50.51	20.56	34.23	40.89
	Std Eff	46.98	45.06	45.06	46.32		44.19	44.19	44.19	44.19	44.19	45.06	45.06	45.06	43.66	44.86
Job 4	Act Eff	49.24	52.63	6.60	52.24	41.41	46.46	56.09	20.46	45.32	36.80	40.66	38.01	26.17	3.79	36.99
	Std Eff	45.34	45.34	38.22	38.22	38.22	48.99	48.99	38.22	38.22	38.22	48.22	48.22	41.16	38.22	42.41
Total 2, 3, 4	Act Eff	48.03	45.82	37.19	40.62	44.83	47.81	46.98	38.29	49.41	45.51	34.62	37.10	33.50	21.37	40.54
	Std Eff	46.06	46.18	44.09	44.51	40.23	46.08	46.53	43.48	43.50	43.50	45.40	46.11	43.76	42.31	44.57
Dept	Act Eff	45.33	51.05	41.51	34.18	36.08	44.62	40.56	42.54	51.04	41.33	38.39	41.36	33.07	29.91	40.79
	Std Eff	46.82	46.82	44.86	42.97	35.00	42.10	42.47	44.78	44.86	44.86	45.39	45.92	44.11	43.01	44.19
WTD	Act Eff	45.33	48.26	46.06	43.01	42.16	42.60	42.29	42.32	43.31	43.11	42.66	42.54	41.72	40.79	
	Std Eff	46.82	46.82	46.18	45.36	44.09	43.73	43.54	43.71	43.84	43.94	44.08	44.25	44.24	44.19	

Note: Budgeted Slasher Speeds are110 ypm.

11.5Appendix E

250 Blend 60W 60F Estimate Summary

ost ype	Description	85.2" 122x122 Standard Cost	92" 122x122 Standard Cost	104" 122x122 Standard Cost	110" 122x122 Standard Cost	117.5" 122x122 Standard Cost
1	Material	.4015	.4331	.4880	.5113	.5459
2	Scrap	.0598	.0646	.0728	.0761	.0813
31	Direct Labor	.3437	.3695	.3923	.3690	.3976
33	Indirect Service Labor	.0473	.0496	.0541	.0600	.0626
1	Other Variable Overhead	.1991	.2086	.2266	.2352	.2458
3	Indirect Production Labor	.1298	.1402	.1540	.1263	.1364
	Total Variable	**1.1812**	**1.2656**	**1.3878**	**1.3779**	**1.4696**
4	Fixed Cash	.2866	.3075	.3437	.3080	.3310
(A	Allocation - Admin General	.0227	.0245	.0273	.0244	.0264
(F	Intercompany transfers	.0058	.0058	.0058	.0058	.0058
(S	Allocation - Group Specific	.0317	.0340	.0380	.0340	.0367
2	Fixed Non Cash	.0901	.0946	.1032	.1461	.1516
	Total Fixed	**.4369**	**.4664**	**.5180**	**.5183**	**.5515**
	Fixed Cash Cost	**.3468**	**.3718**	**.4148**	**.3722**	**.3999**
	Total Cost	**1.6181**	**1.7320**	**1.9058**	**1.8962**	**2.0211**
	Total Cash Cost	**1.5280**	**1.6374**	**1.8026**	**1.7501**	**1.8695**