Application of the Theory of Constraints for Capacity Requirements Analysis: A Case Study

Gary P. Moynihan
Department of Civil, Construction & Environmental Engineering
The University of Alabama
Tuscaloosa, AL 35487-0205
USA

Abstract

The project client, for this case study, would like to move toward the manufacturing strategy of Continuous Flow Manufacturing. This philosophy concentrates on maximizing throughput while simultaneously reducing inventory and operating expense. The initial phase of the project addressed the documentation of the production process at the company, and identification of process constraints. A constraint analysis was conducted using a set of linked Excel worksheets. In parallel, an analysis of quality defect causes was accomplished. Based on feedback from company management, a set of follow-on projects, regarding the Finishing Department, were determined. These included an analysis of labor cost drivers, and analyses of the hazing and sanding processes. Recommendations for improvement were established for these manufacturing processes.

Keywords: Theory of constraints; continuous flow manufacturing; furniture industry; productivity improvement.

1. Introduction

The project client has been an established cabinet manufacturer for over twenty-five years. The company builds "Euro-style" frameless cabinets to order from in-house stock, and doors purchased from outside vendors. Products include over fifty combinations of styles, colors, and woods. The products are sold and delivered throughout the east coast of the United States. Manufacturing leadtime at the company is currently nine weeks (from receipt of order from the customer to receipt of product by the customer). In order to maintain competitiveness with the rest of the industry, company management is attempting to reduce this leadtime to three weeks. They would like to move toward a manufacturing strategy referred to as Synchronous Product Flow or Continuous Flow Manufacturing (CFM).

This philosophy concentrates on maximizing throughput while simultaneously reducing inventory and operating expense (e.g. Shah and Ward, 2003). CFM is a common sense approach that concentrates on turning raw materials into finished products as quickly as possible, and with no wasted effort. It focuses on improving production process bottlenecks (i.e., constraints) to the exclusion of all other improvement efforts. A constraint is defined as any element of the production system that prevents the system form achieving the goal of making more money (Martinelli et al, 2001). There are typically a small number of constraints in any production system that limits its current performance.

An improved process that permits companies to move toward CFM in a systematic way, with maximum benefit for the effort expended, is called the Theory of Constraints (TOC). This theory was originated by Eliyahu M. Goldratt, and was first described in his educational novel, The Goal (2004). The author discussed refinements to his theory in subsequent books (e.g., Goldratt et al, 2000; Goldratt and Goldratt-Ashlag, 2010). The Theory of Constraints facilitates the examination of assumptions underlying traditional manufacturing rules, policies, and measures (e.g. Stein, 1997). It focuses on the few critical constraints that limit the success of the system. Further, it precludes suboptimization by ensuring that solutions to complex problems are effective at the company level. The TOC five-step methodology is defined as (Hutchin, 2002):

1 Identify the manufacturing process constraint. This is typically a physical constraint (requiring additional capacity) or policy (requiring modification of an erroneous policy), although a complete list of constraint classes may include marketing, material, logistics, management, and organizational behavior issues.

2. Exploit the manufacturing process constraint. Wring every bit of productive throughput out of the constraining subprocess as it exists today (e.g., through overtime, more machine uptime, faster machine speed, and reduced scrap).
3. Subordinate everything else to the constraint. If the constraint can only process one hundred units, there is no need for other resources to process more. The factory must adjust other machine operations and logistics moves so that the constraint is always loaded and operational.
4. Elevate the constraint. This is accomplished only if we are unable to break the constraint in the first three steps, and involves spending money to elevate the capacity of the constraint to a level at which it is no longer the constraining subprocess in the system.
5. Repeat the process. Once the current constraint is removed, operations should be stabilized and throughput reexamined in order to identify any new constraints requiring upgrading. Frequently, these opportunities become apparent while working on steps 1 – 4 (Palmetier and Crum, 2002).

2. Methodology

The research team was contacted by the company to develop a plan for an integrated series of projects to improve production throughput. A series of interviews was conducted with manufacturing personnel. Several previous productivity improvement studies were also reviewed. These previous studies suggested a variety of individual improvement projects which had not yet been implemented by the company. This hesitation was due to the uncertainty of whether the local improvement would really affect the overall line throughput.

The initial phase of this project addressed the documentation of the company's production process, and identification of the process constraints. This included documenting the production process using an appropriate flowcharting technique, and documentation of the production rates of key subprocesses (i.e., stations) consistent with the guidelines presented by Woeppel (2001). Investigation also included identification of any clues for the causes of the range (i.e., variation) in order completion times based on the description of the order to be filled, as well as any historical notes on problems encountered in completing each order.

The research team suggested applying the Theory of Constraints within an overall context of gap analysis. A gap analysis compares an existing situation with a target (Blanchard and Fabrycky, 2010). Differences (i.e. deltas) between the two baselines are identified and quantified. Plans are then established to resolve these differences as a transition to the desired objective. This approach is represented in Figure 1 in the form of a high-level input-process-output (HIPO) chart. Individual productivity improvement projects would be evaluated using the Theory of Constraints (i.e. what is the project's impact on the production constraining points). A prioritized list of productivity improvement projects could then be established, thus insuring the best value for the company's investment (Hutchin, 2002).

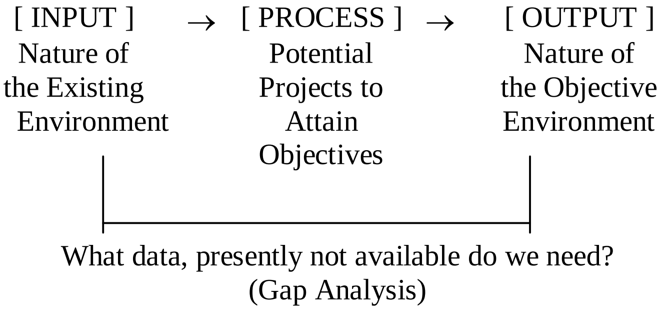

Figure 1: Summary Linkage of Efforts Which Incorporate the Gap Analysis Approach

Based on this initial investigation, and with the guidance and concurrence of company management, specific constraining operations were analyzed during the second phase of this research. Recommendations for exploiting/elevating the constraints, in the form of manufacturing methods improvements, were determined. The impact of these proposed changes on company production volume was quantified and documented.

3. Constraint Analysis

The first step in the Theory of Constraints' five-step methodology is identification of the manufacturing process constraint. This infers a clear understanding of the current manufacturing process flow.

This was documented with a set of integrated flowcharts, showing the precedence of operations for both priority and nonpriority orders in the milling, finishing, and assembly departments. The administrative steps in processing these orders, prior to their manufacture, were also flowcharted (Woeppel, 2001). Operational times were then determined for each step in the flowcharts. By identifying the work center associated with each operation, this also provided insight into the amount of time each work center has to contribute toward meeting a given production demand.

3.1 Roughcut Capacity Analysis

This acquired data was used to determine the manufacturing constraints through a process referred to as roughcut capacity analysis (Ptak and Schragenheim, 2000). RCCP is an intermediate horizon (1 – 26 weeks) production planning tool. It calculates the total workload capacity for a given resource or set of resources. Although the Theory of Constraints considers throughput in financial terms (e.g. Kaplan and Anderson, 2007; Ray et al, 2008), conventional roughcut capacity analysis addresses throughput in terms of production volume (Robertson 2008). This was the context that the company management preferred that we use. RCCP analysis only calculates production volume on a weekly or monthly basis. It is not a scheduling tool, since it does not consider such manufacturing variables as transportation and queue times (Ptak and Schragenheim, 2000). However, it may support effective scheduling by comparing production schedules to the available capacity, and thus avoiding the problems associated with infinite capacity scheduling (Robertson, 2008).

RCCP is executed by combining data on planned and released orders with the product structure and operational data from the bill of material and router file, respectively (Ray et al, 2008) It projects the amount of product that the resource (e.g. production line) is capable of producing within a given time period. RCCP then compares this available capacity with the projected capacity required (i.e. scheduled quantities times the required duration to manufacture the product). A more extensive computer simulation model also was considered for this project, but this alternative was rejected due to time constraints and software availability.

According to Robertson 2008), traditional approaches to roughcut capacity analysis make a variety of assumptions. For example, RCCP does not consider available production batch capacity. This traditional approach was modified to consider capacity on a per order basis, consistent with the company's method of business, and also address some of these stated deficiencies. This analysis linked the product bills of material, delivery schedule, operational times, and work center characteristics through a set of integrated Microsoft Excel spreadsheets as noted in Figure 2.

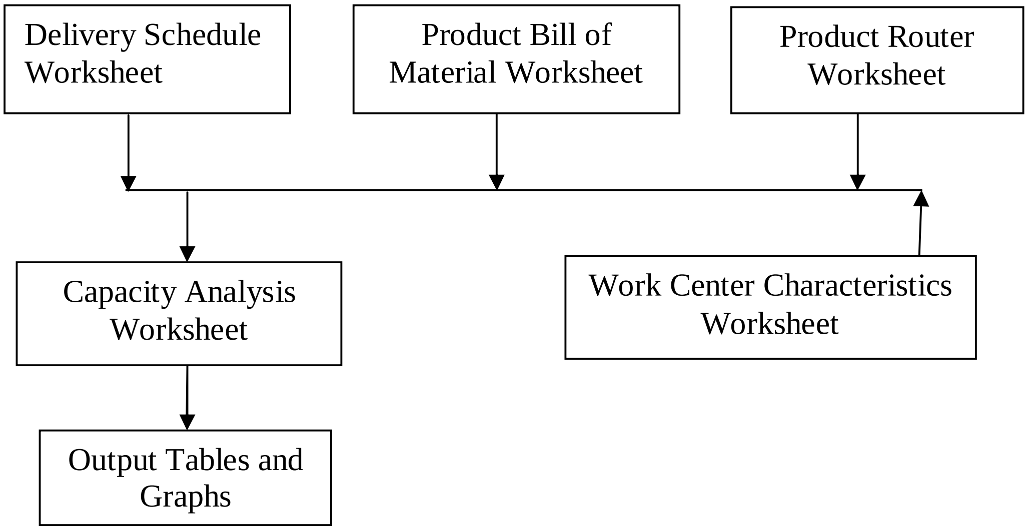

Figure 2: Constraint Identification Through Excel Roughcut Capacity Planning Approach

3.2 Modified Standards File

As in most production planning and scheduling systems, the bill of material and the router file represent the fundamental data sources used for subsequent processing. Within the router file, the standards represent time estimates for normal task durations. In a manufacturing environment, the standards file provides data to drive such functions as production planning and scheduling, estimating, and performance measurement.

However, it has long been recognized that the resulting production plan may be in error due to the inclusion of incomplete operational aspects (e.g. Dos Santos, 1995). Although some classical industrial engineering techniques provide insight into these aspects, the standards data are not stored in a structure adequate for detailed production planning.

A reconfiguration in the structure of the standards data, as originally proposed by Moynihan et al. (2002), was incorporated into the worksheets. This restructuring has significant implications for the improved accuracy of production plans, and the enhanced affordability of the resulting product. The standards file restructuring is based on the concepts of Activity-Based Costing, to better support these identified production planning functions (e.g. Kaplan and Anderson, 2007). As noted in Figure 3, this reconfiguration s takes the form of a ten-element standards matrix at the operational level. The matrix allows time estimates to be derived from the perspectives of the operator, the equipment, and the part, all on a per lot, per batch, and per piece basis. The tenth element comprises the standard batch size, and reflects the fixture capacity of the machine.

	Labor	Machine	Part	Standard Batch
Per Lot	25	40	15	
Per Batch	20	60	60	5
Per Piece	1.5	0	0	

Figure 3: Standard Time Matrix for Specific Cabinet Manufacturing Operation.

This standard batch size field is required for subsequent RCCP calculations involving batch-level durations as noted in Equation 1. This research has further formalized the standards matrix, and the algorithms which subsequently utilize the data, such as Equation 1.

Total Machine Time = $mach_{lot} + (lot_{size}/batch_{size}) \times mach_{batch} + (lot_{size} \times mach_{piece})$ Equation 1

3.3 Results of Capacity Analysis

This spreadsheet approach provides an effective production planning tool, particularly for what-if analysis. In this specific analysis, total working time was predicated on the three-week leadtime target.

Representative orders were processed through the spreadsheets. The same capacity constraints were identified with each run. The calculated requirements are similarly represented in both tabular and graphical form. On the resulting graph, the individual work centers are identified along the x-axis. (See Figure 4.) The identification is based on the operation sequence number on the flowcharts. The percent utilization is indicated by the y-axis. According to the American Production & Inventory Control Society (APICS), a long-accepted rule-of-thumb is that any operation with an 85% utilization, or greater, is a potential production bottleneck (APICS, 2003).

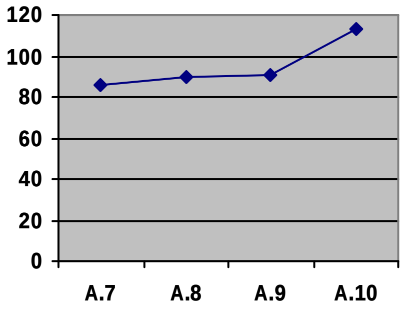

Figure 4: Example of Spreadsheet-generated Utilization Analysis Chart

Table 1 highlights these top six constraining operations. It is to be emphasized that this sequence is based upon the specific combination of orders analyzed by the capacity analysis spreadsheet.

The output may vary somewhat if a different set of orders were used as input. However, the constraining operations identified in this table did confirm the manufacturing department managers' opinions regarding the location of process bottlenecks within their respective departments.

Table 1: Top Six Constraining Operations

Operation Number	Operation Name	Department	% Capacity Utilization
NP.10	24 Hr Approval Period	Orders Department	422
A.7	Special Assembly	Assembly Department	80
A.8	Clamp Operation	Assembly Department	90
A.9	Hot Melt	Assembly Department	91
A.3	Sort for Assembly	Assembly Department	84
A.10	Drawer Rail Install	Assembly Department	113

With regard to Table 1, Operation NP.10 is a 24 hour delay in order processing to obtain credit approval regarding the customer. This was identified as the highest priority constraint. Since the bottleneck is due to a company internal policy, it was recommended that this process should be analyzed so that guidelines could be developed, the policy modified, and the flow of new orders expedited. The next set of constraint operations identified, all occur in the Assembly Department. Based on feedback from the Assembly Department manager, there are various individual causes for each of the constraining operations. However, these four operations occur together in sequence. This implies that there may also be a common underlying problem.

During the analysis, other issues were identified which also require follow-up investigation. For example, the Milling Department's Gannomet machine has a 74% utilization rate. This is due to a relatively high rate of downtime. Although this did not result in a process constraint operation in this analysis, it might for a different combination of orders. It was also noticed that scheduling and management in the individual departments are based on local optima, i.e.:

- Ordering is based on order number.
- Milling is based on millcut optimization and product group.
- Finishing is based on finishing type.
- Assembly is based on product and order number.

The objective of this, within each manufacturing department, is to minimize the number of set-ups. This is considered to be a basic responsibility of any production manager. However, as noted by Goldratt (2004), this strategy may not necessarily meet the company's objectives of shipping completed orders on-time.

Finally, the Finishing Department operations were problematic. The particular order data, which we received for this analysis, did not exercise the finishing operations a great deal. There were some questions regarding the operational times, as well. Production analysis was complicated by the rework volume within the department. This initiated an analysis of quality defect causes, which is discussed in the following section.

4. Quality Analysis

The second step in the Theory of Constraints deals with exploiting the manufacturing constraint. This emphasizes obtaining all possible productive throughputs from the constraint in its current configuration (Hutchin, 2002). One aspect of this step is that only "good" parts should be processed by the constraint; i.e. scarce capacity can not be wasted on defective parts (Woeppel, 2001). Company data, for the previous year, were analyzed regarding defect causes for backorders, shipped loose, and claims against the company. Pareto diagrams by cause code, and time graphs of monthly fluctuations were developed.

Based on this analysis, the following were recommended for immediate action:

1 Initiate retraining in order to reduce finishing defects (specifically sanding, edges, too light/too dark, and paint coverage) on doors and drawer fronts.

2 Eliminate delays in inspecting doors and drawer fronts from the supplier. The delay in inspection, until the start of finishing, appears to be causing many of the subsequent problems. It was recommended that a 100% inspection be conducted at the time of delivery. Unacceptable product should be marked in order to educate the supplier’s production manager. All rejects should be documented, particularly as a basis for requesting financial compensation.

3. Implement an interim measure to prevent milling defects from reaching the Finishing and/or Assembly Departments prior to detection. This can be accomplished either by 100% inspection of all parts leaving the Milling Department, or by having a roving inspector who verifies work while in process. The possibility of this slowing production in milling is secondary, since the Milling Department was not identified as having any production constraints.
4. Appoint one person to handle all rework/reorder logbooks. This will insure consistency, and improve the accuracy, of part tracking and close-out.

The introduction of quality control inspection points is imperative to stop wasting constrained resources on defective parts (Hutchin, 2002). This will result in an almost immediate improvement in the production of good parts. This may be considered to be a short-term approach until operator training is successfully implemented. It is only after this training is completed, should individual operators inspect their own work.

After implementing these recommendations for immediate actions, other quality-related initiatives should be enacted in order to correct the underlying problems:

1. Root cause analysis and develop preventive actions for scratches.
2. Root cause analysis and develop preventive actions for black spots.
3. Root cause analysis and develop preventive actions for milling defects found in finishing and/or assembly.
4. Identify and cost-justify permanent quality control inspection points throughout the plant. Identify associated quality standards and manloading. Determine whether a quality manager and quality control department are needed for future market growth/financial success at the company.
5. Root cause analysis of the top ten causes of claims and develop preventive actions.
6. Root cause analysis of the top five causes of back orders and development of preventive actions.
7. Pareto analysis of "Past Due Priorities", with associated impact assessment, root cause analysis, and development of preventive actions.
8. Analysis of shipping department operations for quality and efficiency improvements, e.g., concealed shipping short, concealed shipping damage, verified shipping damage, poor workmanship and other company errors in shipping, facility and truck constraints.

5. Direction for Phase 2

The Theory of Constraints implies a different paradigm for addressing accounting issues. As noted by Goldratt and Goldratt-Ashlag (2010), product cost is traditionally considered to be the primary method to understand value and make effective business decisions. Yet, traditional accounting approaches may be based on flawed assumptions (e.g., focusing on local optima; how inventory is addressed) and lead to erroneous decisions. As noted by Smith (2000), “Improvements in one area cannot be gained at the expense of another area of the business, if both are necessary for the business to succeed”.

Conversely, TOC is based on three definitions (Ray et al, 2008):

1. Throughput is all of the money that is obtained from selling the product (i.e. revenue minus raw material cost).
2. Inventory is all of the money allocated in fixed assets that is used to produce throughput. (The primary difference with TOC is that fixed assets and conventional inventory are treated the same.)
3. Operating expenses are all of the money spent to produce throughput.

A series of TOC-based metrics (e.g. net profit, return on investment, inventory turns, and productivity) are then formulated based on these definitions. This results in a better alignment of internal resources “so that they can act in concert to improve and execute the (business) strategy” (Smith, 2000).

These accounting ramifications of TOC are considered too radical for many organizations. Hutchin (2002) provides several case studies highlighting conflicts encountered when trying to apply constraint management theory to a company’s revenue chain. Organizational inertia and apprehension frequently impede its successful implementation. In Unconstrained Organizations (Hutchin, 2000), the author refers to this institutional barrier to change as “paradigm lock”. This is precisely the situation encountered in this case study. Company management was comfortable with the existing accounting system, and was reluctant to change it. The project team was explicitly directed to apply more conventional cost approaches during the subsequent phase.

A briefing was conducted to company management. The results of the constraint and quality analyses were presented. It was agreed that the Finishing Department should be the focus of the second phase of this project, due both to insufficient process documentation/data, as well as the level of rework. Of immediate concern to the company's management was the department's high labor costs reported for the previous month. Phase 2 of this project included an analysis of labor cost data for the Finishing Department in order to determine the cost drivers (i.e., causes) for the recent trend in labor dollars per product (internally referred to as a "box"). The project team was also directed to determine standard methods for the finishing processes of sanding and hazing. This would include observing and documenting the current operation, and determining recommendations for an improved method.

5.1 Analysis of Labor Cost Drivers

Based on management direction from the March 11 meeting, an analysis of labor costs in the Finishing Department was conducted. The objectives of this analysis were to:

1. Ascertain why the February labor costs were so comparatively high.
2. Provide insight into how labor costs in the Finishing Department can be reduced.

Based on the assumption that the manufacturing process is in statistical process control, a series of control chart analyses were initiated. These control charts were developed using Excel and Statgraphics software. A variety of data was plotted, including cost data (e.g. total labor cost/total boxes produced, finishing labor cost/finished boxes produced, other department’s labor cost/total boxes produced, and finishing labor as a percentage of total labor) and potential cost drivers (e.g. quantity of boxes produced, quantity of people employed, turnover, production mix, changes in overhead rate, quality and rework metrics, and changes to the manufacturing process). The individual control charts were reviewed. Consideration was given to any evidence of trending, as well as identifying any points outside the control limits. Any of these points were investigated further for their cause. The individual control charts were also compared for common patterns. It was found that record levels of the percentage of finishing due to hazed products, primarily contributed to the next month’s high labor costs, since these products are more labor intensive. Other contributing factors were a low production month, possibly due to the recent "stop-the-line" policy, as well as an extremely high turnover percentage (15%). The July period appeared as the only other outlier point on the control charts. Like the February data, it was caused by another low production month (in this case probably due to production changeover), and an extremely high turnover percentage.

Analysis of the data also indicated a trend of increasing total cost from November to January. This was due in part to an increase in the number of employees in the department (up 10% from the preceding January levels). The trend primarily reflected the growing percentage of boxes that were hazed. For example, in October, 35% of the department's output were hazed products. By the following January, this had grown to 51%.

The Finishing Department control charts were compared to those of the other departments. It was observed that shipping costs have been below average for the last two years and are statistically stable. Assembly costs are also stable, but slightly above average for the last five months of the analysis period (October - February). Milling costs have been statistically stable for the past four years. In general, all three departments experienced minor spikes on their individual control charts in July and February, probably due to the low production and high turnover rates identified in Finishing.

In summary, the primary labor cost driver in the Finishing Department is the percentage of products hazed. To some extent, this is simply a cost of doing business for this type of product, and should be considered when establishing a sales price. This cost may be moderated or reduced through the implementation of the process methods improvements identified in the next sections. In addition, high turnover, high rework, and production disruptions were responsible for labor cost increases across departments, and should be avoided.

5.2 Analysis of the Hazing Process

Hazing is a finishing process that provides wood with an antique look. In order to establish a consistent method and instructions for hazing, the current process was observed and data were collected and documented. This included the steps of the hazing process, the times for hazing work pieces, the distances that the work pieces travel through hazing, the layout of the work area, the number of workers required for the department, and the production mix per week..

The data was analyzed in order to determine where improvements could be made. Each work piece is hazed in a similar manner. However, they do not enter and leave the hazing area in the same location. It was observed that not all of the work pieces are required to be cleaned after being hazed. Further, the hazing process is complicated due to the different categories and sizes of the work pieces.

Due to this difficulty, Methods-Time Measurement (MTM-1) was used to determine standard times. According to Neibel (1993), MTM is "a procedure which analyzes any manual operation or method into the basic motions required to perform it, and assigns to each motion a pre-determined time standard which is determined by the nature of the motion and the conditions under which it is made". The work pieces were grouped by doors, small ends, tall ends, molding, and plywood. The standard times generated for these by MTM-1 were checked by comparing them to an average process time for consistency. Observations of the current hazing process identified three areas for potential improvement: the hazing method, walking distances, and the application of wiping stain.

Two alternatives were developed in order to improve the problem areas of the hazing process. Alternative 1 encompasses the fastest method for hazing and a new spraying tip for the spray guns. No changes to the current layout are made. Alternative 2 is comprised of the fastest method for hazing, a new spraying tip for the spray guns, reduced walking distances to the work pieces, small ladders for the workers, and a small spray gun for the inspectors. The two alternatives increase the number of work pieces hazed in less time. They accomplish this by making the process more efficient, i.e. two workers can haze the molding and tall ends at the same time, while four workers can haze the plywood in one third of the current time. By dividing the number of process steps among the workers, the number of doors and small ends hazed will increase dramatically.

Based on the analysis, alternative 2 is recommended. The decreased walking distances associated with it dramatically increases production volume. The small ladders would be used by the workers in lieu of currently standing on the movable racks. The racks are unstable and are a potential source of accident and injury. The spray gun associated with alternative 2 would allow the worker to clean the doors and small ends in approximately half of the current time. The estimated cost of alternative 2 is $155. This cost is more than offset by a 37% reduction in time to haze the current production mix.

5.3 Analysis of the Sanding Process

An analysis of the Finishing Department's sanding process was conducted in parallel to the hazing process analysis, using the same general approach and steps. The current sanding process was observed and documented, with particular attention to studying the layout of the sanding area. Time studies were performed on the transport of unsanded orders and finish sanded orders on each table in the current layout situation. This provided the basis for the generation of alternative recommendations for process improvement.

The first alternative consisted of two proposed layouts of the sanding area.The purpose of these layout changes was to minimize the distance traveled on the conveyor by both new and finished orders. The changes will also minimize the distance that operators have to walk in order to retrieve new orders and to transport finished orders. Decreasing this distance will shorten the cycle time, and thus increase the production volume of the finished boxes. Three detail sanders were also considered: heavy duty detail sander, Milwaukee narrow-belt sander, and a Porter cable profile sander kit. These tools would improve the efficiency of sanding tight edges and corners. Finally a revised sanding method was investigated. The revised method would minimize the number of required hand motions for sanding. An accompanying MTM-1 analysis was performed for this alternative.

Six combinations of alternatives, were evaluated based on increased production volume, increased safety, floor-space savings, improved standard method, and cost. Based on this analysis, alternative L1xT3xM1 (i.e., layout 1, tool 3, and standard method 1) was recommended. Although it is comparable in cost to alternative L2xT3xM1, at $1,028, it provides greater floor space savings and efficiency improvement. L1xT3xM1 resulted in an increase of efficiency of 3.4% (comparable to four more completed orders).

6. Conclusions

The Theory of Constraints facilitates the examination of assumptions underlying traditional manufacturing rules, policies, and measures (Hutchin, 2002). It focuses on the few critical constraints that limit the success of the system. Further, it precludes suboptimization by ensuring that solutions to complex problems are effective at the company level. The Theory of Constraints was applied in the analysis of cabinet manufacturing operations at a specific company.

A spreadsheet-based computer model of the furniture company's production line was developed. Rough-cut capacity analysis was selected as the approach used to determine these manufacturing constraints. The spreadsheet model produces information used in determining and correcting the causes for the production inefficiencies. Consistent with TOC, after identification of these constraints, a quality analysis was conducted. The associated recommendations to improve quality were intended to ensure that no productivity was lost through inefficient use of the constraining resources.

Based on the direction of company management, labor cost data for the Finishing Department were analyzed in order to determine the cost drivers for the recent trend in labor dollars per box. Although contrary to "pure" TOC theory, the company was still able to accrue benefits from this effort. Statistical analysis, and particularly control charts, were used to determine the effects of random variation. This allowed the identification of trends, as well as weeks with unusually high (or low) labor costs per box. Production rate, product mix, quantity of employees, and other manufacturing variables were investigated as potential causes.

Standard methods were determined for the hazing and sanding operations in the Finishing Department. Existing work instructions for the operations were reviewed. Based on observation and documentation of the current methods, recommendations were developed. These included task descriptions, workstation layout, and identification/placement of needed tooling/equipment. A set of detailed work instructions were developed for the company's production employees. Alternatives that may not be feasible within the current workspace, but could be implemented in a planned facility expansion, were identified and evaluated for their cost/benefit relative to the current operation. These recommendations address the fourth step in the Theory of Constraints.

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